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AND

PROCEEDINGS OF THE SOCIETY OF ARTS.

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PROCEEDINGS OF THE SOCIETY OF ARTS.

THIRTY-FIFTH YEAR, 1896–97.

THURSDAY, April 8, 1897.

THE 498th meeting of the SOCIETY OF ARTS was held at the Institute this day at 8 P.M., with Mr. Blodgett in the chair.

The record of the previous meeting was read and approved.

Messrs. Frank L. Fales, of Boston, Levi G. Hawkes, of Saugus, F. Herbert Snow, of Brockton, Otis Bigelow, of Washington, D. C., George W. Fuller, of Louisville, Kentucky, and Miss Grace A. Van Everen, of Brooklyn, New York, were duly elected Associate Members.

The Chairman introduced Mr. L. H. Parker, of Schenectady, New York, who read a paper on "Heavy Electric Railway Service." The paper opened with an account of the development of the electric motor, and then descriptions were given of various devices used in electric railway service, such as the electric brake, the automatic circuit breaker, magnetic fuse box, conduit plow, regulating devices, and switch boards. Then the advantage of electric power over steam for elevated roads was discussed, and its superiority was attributed to the more rapid acceleration which it allows. The use of the third rail was spoken of as applied to both surface and elevated roads, and the

speaker closed with a description of the electric locomotive of the Baltimore & Ohio Railroad. The paper was illustrated by models and lantern views.

Professor Swain and others took part in the discussion which followed. It was voted to thank Mr. Parker for his very interesting paper. The Society adjourned.

THURSDAY, April 22, 1897.

The 499th meeting of the SOCIETY OF ARTS was held this day at the Institute, at 8 P.M., with Mr. Blodgett in the chair.

The record of the previous meeting was read and approved.

The Secretary presented a report from the Executive Committee recommending that the BY-LAWS of the Society be amended by striking out the word "four" in the last sentence of Section II, and inserting in its place the word "three," so that the sentence shall read, *Three members shall constitute a quorum for the transaction of business.* A letter from the Secretary of the Corporation was read, showing that this amendment had been approved by a vote of the Corporation, March 10, 1897. The amendment was then laid upon the table, as required by the BY-LAWS, to be considered at the next meeting.

On motion of Colonel Hewins it was voted that the Chair appoint a committee of five to nominate the Executive Committee for 1897–98. The Chair appointed Messrs. James P. Monroe, E. K. Turner, Charles A. Stone, A. E. Burton, and Charles T. Main.

There being no further business, the Chairman introduced Mr. George B. Francis, resident engineer of The Boston Terminal Company, who spoke on "The Engineering Problems of the New Southern Station." The history of the project was sketched briefly, and then a number of the problems involved were stated, and it was shown how it is proposed to solve them. In order to provide separate platforms for baggage, the number of stub tracks had to be reduced to 28, only 3 more than the aggregate of the present southern stations. But electricity as a motive power and the growth of suburban traffic had to be taken into account. The necessity of providing larger facilities under these conditions leads to the introduction of one of the most interesting features of the plan. This is the underground suburban loop,

consisting of two tracks with a radius of 262 and 242 feet, respectively. In order that there shall be no steps in the approaches, it was necessary to put the loop tracks 2 feet below high-water level. The waterproofing presented the most difficult problem. Gravel concrete is used to avoid cutting the waterproof material. The drainage area of the roof of the train shed is $12\frac{1}{2}$ acres. The tracks will require the largest interlocking plant in the world. There are at present 650 trains daily leaving and entering the southern stations, of which about 400 are suburban. The loop track will give double the capacity of any existing station.

During the discussion which followed Mr. Francis said that borings show that the foundation is blue clay, overlying strata of clay, sand, and gravel. The waterproofing consists of courses of felt with tar, etc., and the concrete is used to hold it in place. The roof is to be so strong that the snow may be allowed to remain upon it.

On motion of Colonel Hewins it was voted to extend to the speaker the thanks of the Society. The Society then adjourned.

THURSDAY, May 13, 1897.

The 35th Annual Meeting (500th meeting) of the SOCIETY OF ARTS was held at the Institute at 8 P.M. on this day, Mr. Blodgett in the chair.

The record of the previous meeting was read and approved.

Messrs. John Balch Blood, of Boston, George H. Hamlin, of Orono, Maine, Everett Morss, of Boston, Thomas M. Lothrop, of Brookline, Henry K. Rowell, of Brunswick, Maine, were duly elected Associate Members of the Society.

The Secretary read a communication from the Committee on Nominations, in which the following gentlemen were named as candidates for the Executive Committee: George W. Blodgett, Desmond Fitz Gerald, Thomas Doane, E. H. Hewins, and F. W. Hodgdon. Ballots having been cast, it was found that a quorum was not present, and all business appertaining to the Annual Meeting was laid on the table.

The following papers were presented by title:

"A Tribute to the Memory of Brevet Brigadier General Francis Amasa Walker," by Thomas L. Livermore.

"Claims of Modern Life on Education," by William T. Sedgwick.

"Some Data on the Heating Error in Resistance Coils," by F. A. Laws.

"Studies of the Eskimos of Baffin Land and Umanak Fiord, Greenland," by R. W. Porter.

"Formation of Diacetylenyl (Butadiine) from Copper Acetylene," by A. A. Noyes and C. W. Tucker.

"A Note on Some of the Requirements for a Sanitary Milk-Supply," by W. T. Sedgwick.

The Chairman introduced Captain John Bigelow, Jr., 10th United States Cavalry, Professor of Military Science at the Institute, who read a paper on "Military Education." He said that from the point of view of the soldier, a man consists of three parts — physique, morale, and intellect. The various qualities of each of these parts should be developed by a military education. He gave an outline of the course of instruction at West Point, and pointed out how far this meets the requirements of a complete military education. Post instruction and service schools were then spoken of as valuable features of the American system. The paper closed with an argument for special schools for staff officers where they could receive instruction of a university grade.

A discussion followed, after which a vote of thanks was extended to the speaker for his valuable paper, and the Society adjourned.

THURSDAY, May 27, 1897.

The 501st meeting of the SOCIETY OF ARTS was held this day at 8 P.M., Professor Richards in the chair.

The record of the previous meeting was read and approved.

By unanimous consent the other business of the evening was postponed until after the reading of the papers.

The following papers were presented by title:

"Velocity of Reaction between Ferrous Chloride, Potassium Chlorate, and Hydrochloric Acid," by A. A. Noyes and R. S. Wason.

"Some Fundamental Propositions Relating to the Design of Frameworks, a Study of Primary Stress in Indeterminate Frameworks, and Demonstration of the Economic Superiority of Statically Determined Frameworks," by Frank H. Cilley.

"A Flavor-producing Micrococcus of Butter," by S. C. Keith, Jr.

Mr. Timothy W. Sprague was introduced and read a paper on "Application of Electricity to Mines," in which he gave a history of the progress made in employing electricity in various mining operations, such as hauling, hoisting, drilling, coal cutting, and pumping. He closed with some remarks on the electrical transmission of power to mines.

A discussion followed, after which it was voted to extend to the speaker the thanks of the Society.

The unfinished business from the Annual Meeting was then taken up. The following report was presented by the Executive Committee:

ANNUAL REPORT OF THE EXECUTIVE COMMITTEE.

With the close of this thirty-fifth year of its existence the SOCIETY OF ARTS will have passed its five hundredth meeting. During the present year there will have been held fourteen meetings, at which fifteen papers will have been read. One meeting was a special one held jointly with the Boston Society of Civil Engineers to listen to a paper on "The Tampico Harbor Works," by the eminent engineer, Mr. E. L. Corthell. Three notable papers have been presented showing the summer work of the Institute. One of these was by Professor Homer, on the "Summer School of Architecture in Europe." The other two were by Professors Burton and Barton, on the "Scientific Work of the Boston Party on the Sixth Peary Expedition to Greenland." All three of these papers will be published in the current volume of the TECHNOLOGY QUARTERLY, and, in addition to these, an exceptionally valuable article on the "Pendulum and Magnetic Observations" has been contributed by Mr. Putnam, a member of the Boston party. Another paper that deserves special mention, both because of its intrinsic value and because it embodied the results of original work done by a member of the Society, and largely in the laboratories of the Institute, is the paper read by Dr. Williams on "Some Uses of the Röntgen Rays."

The endeavor has been made, as far as possible, to publish the papers presented before the Society in the TECHNOLOGY QUARTERLY, but some papers have been crowded out or have been much delayed owing to lack of space. As it is, the size of the last two numbers of the QUARTERLY has been much greater than the finances of the Society will warrant, and future numbers will have to be smaller, even if that necessitates the omission of valuable contributions. The "Results of Tests Made in the Engineering Laboratories" are regarded as an especially valuable feature of the QUARTERLY, and, although a source of very considerable expense, they will continue to be published as presented.

The most momentous event in the history of the Society during the year is the death of President Walker, which has been felt more keenly, perhaps, by the members of the Executive Committee than by the other members of the Society, for their duties brought them into closer personal relations with him, and they have been better able to observe the thoughtful interest and wide knowledge of affairs that General Walker brought to the aid of the Committee in its efforts to guide the course of the Society.

At the time of the previous Annual Meeting the Society had 67 Life Members. Eight of these have died during the year, leaving 59 as the present number. The number of Associate Members a year ago was 289; 3 have died and 11 have resigned. This loss has been more than offset by the election of 35 new members, making the present number of Associate Members 310.

The Life Members who have died during the year are Thomas T. Bouvé, George O. Carpenter, William O. Grover, Henry D. Hyde, G. F. H. Markoe, O. W. Peabody, John Ruggles, and George W. Wales; the Associate Members, are Henry A. Craigin, James H. Stanwood, and Francis A. Walker.

Respectfully submitted,

GEORGE W. BLODGETT,
PERCIVAL LOWELL,
ROBERT P. BIGELOW,
For the Executive Committee.

The election of officers being next in order, ballots were cast and the candidates for the Executive Committee presented at the previous meeting were declared duly elected. Mr. Blodgett reported that the Executive Committee had nominated Dr. Robert P. Bigelow for Secretary for the ensuing year. The Society proceeded to ballot for Secretary, and Dr. Bigelow was duly elected.

Mr. Elisha Lee, of Port of Spain, Trinidad, was elected an Associate Member. It was then voted to adjourn.

ROBERT P. BIGELOW, *Secretary.*

SOME DATA ON THE HEATING ERROR IN RESISTANCE COILS.

By FRANK A. LAWS, S.B.

Received January 27, 1897.

In spite of the fact that Wheatstone bridges and resistance boxes of precision are in common use in our laboratories, there seems to be a lack of reliable data as to the heating error that is likely to occur under the ordinary conditions of use; and I am not familiar with data which will allow one to form a just estimate of the error likely to occur when a coil of a given resistance and of a specified size of German silver wire, wound on a wooden bobbin and inclosed in the neighborhood of other coils in the ordinary closed box, is subjected to a specified current for a stated time.

It was with a view to supplying some of the important data mentioned above that the following experiments were undertaken. They were performed under my direction at the Rogers Laboratory of Physics, by Mr. K. A. Pauly, in connection with his thesis during the spring of 1896.

The box tested was a Wheatstone bridge, the coils of which were wound with double silk-covered German silver wire of the sizes recommended by Professor Holman in his *Physical Laboratory Notes; Part II, Electrical Measurements.*

The coils were wound on wooden bobbins 7.5 cm. long; the diameter of the core was 1.0 cm. They were supported in the box in the usual manner by brass rods 0.5 cm. in diameter. The coils were paraffined by immersion in hot wax under the bell jar of an aspirator, and were well drained so that there was no excess adhering to the outside. The inside dimensions of the closed box containing the coils were 36.5 x 20. x 13.5 cm. For the determination of the increase of resistance a special Wheatstone bridge was arranged as indicated in the sketch, where it is shown without the complications of the other necessary connections.

Nominally equal resistances were unplugged in *Br* and *X*, and an exact balance obtained by the slide wire. If the extension coils, which are of equal value, be properly proportioned to the resistance of the slide wire, one turn may be made to represent a given percentage change in *X*, in our experiments $\frac{1}{10}$ per cent. The boxes *X* and *Br*, as well as the extension coils, were all placed in a large constant temperature tank. The galvanometer circuit was kept closed, and that of the battery made and broken by the special switch shown in the accompanying sketch (Figure 2), the closing of which, besides making the battery connection, transferred the coil under test from the heating circuit to the bridge without loss of time. The action of the switch is evident from the drawing and the diagram of the entire apparatus (Figure 3). The mercury cups

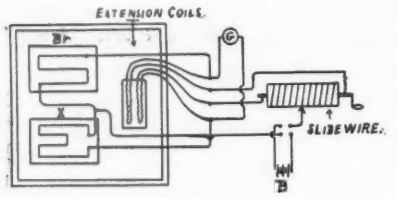


FIG. 1.

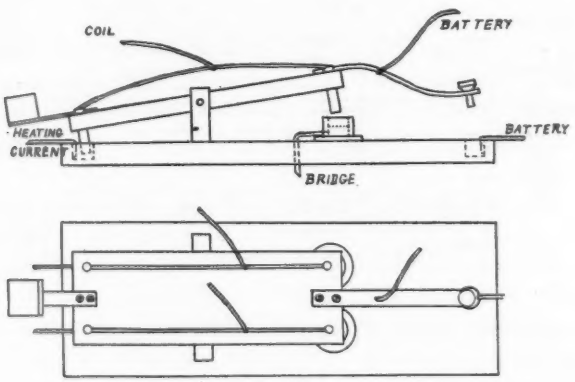


FIG. 2.

(well amalgamated) forming the bridge connections were placed on rubber cushions, so that a good contact would be obtained and no irregularity introduced in consequence of variations of contact resistance.

When the low resistance coils were under test, it was found that the heating of the coil introduced thermo-electric disturbances, in some cases of sufficient magnitude to send the spot of light off the

scale. This was remedied by compensation, by an opposing *P. D.* in the galvanometer circuit. The effect increased as the heating progressed, so that at every reading it was necessary to adjust this *P. D.* anew, but by a little practice the observer was able to anticipate the change, so that this adjustment was a matter of only a few seconds.

The heating currents were measured by Weston ammeters, and as instruments of the proper range were not always obtainable, the bridge under test was shunted with another, the ammeter being placed in series with it and the heating current calculated by the law of shunts.

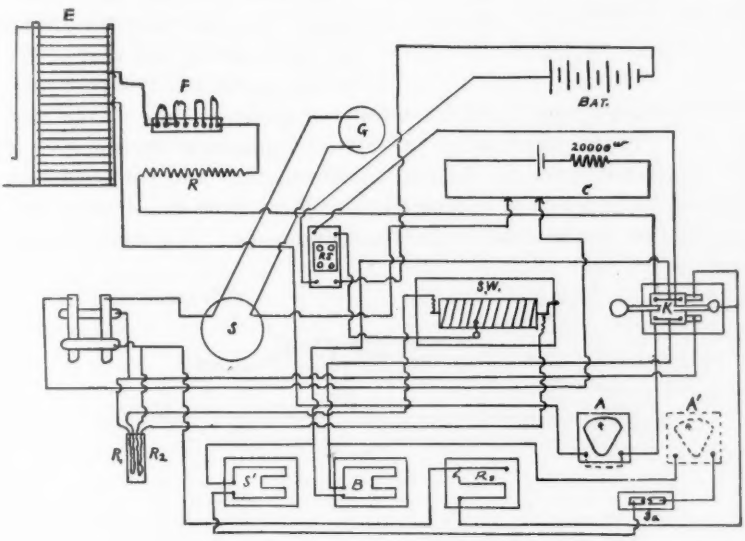


FIG. 3.

The accompanying sketch (Figure 3) shows the arrangement of the entire apparatus.

At *E*, *F*, *R* are seen the resistances for controlling the heating currents which were derived from the 110-v. lighting circuit of the laboratory. *C* is the compensation arrangement before mentioned; *R S* the reversing switch in the circuit; *S* the galvanometer shunt; *S W* the slide wire which is wound on a cylinder; *K* the combined coil, changing switch and battery key mentioned above; R_1 and R_2 the extension coils. *S'* is the shunt used in connection with ammeter *A'* for measuring the heating current when ammeter *A* in direct circuit is

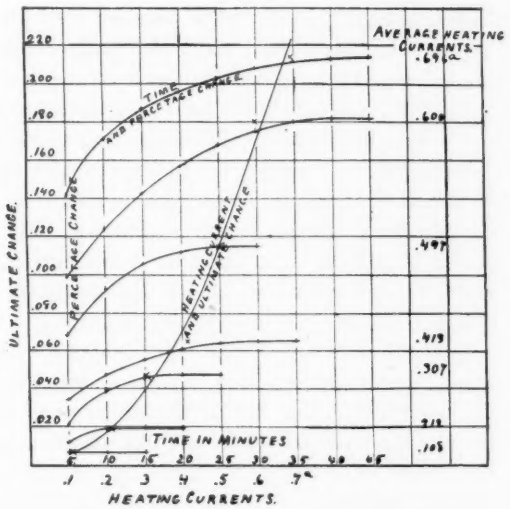
not available. For the purpose S_2 is the plug for cutting out S' and A' when the coil is being measured. B is the bridge under test, and R_3 the resistance box forming the fourth side of the special bridge. The galvanometer used was a 7-ohm Thomson, having a very carefully prepared astatic suspended system. The balancing could be effected to within $\frac{2}{1000}$ of a per cent. except in the case of the coils of very high resistance where the precision was considerably less.

The procedure during the tests was as follows: The coil to be tested was allowed to remain at a constant temperature for a time sufficient to allow the temperatures of its various parts to become the same; a balance was then obtained and a reading of the slide wire taken. A measured current was then sent through the coil, and the balancing repeated every five minutes until the resistance came to its permanent state for the particular heating current employed. The results of the experiments will now be given in the form of plots, and for greater convenience the same scales of time, percentage change, and ultimate change are used throughout. The scale of heating currents is varied to suit the case in hand. The plots of current and ultimate change enable one to design a coil of a specified resistance, to be made of the size of wire here used, which will carry a given current indefinitely and not increase in resistance more than an assigned percentage, provided the increase be less than $\frac{2}{10}$ of one per cent.

To use these curves it is, of course, necessary to wind the coils of the same diameter as those tested, and to vary the resistance by altering the length of the coil. The dimensions of the coils are only approximate, as no attempt was made to wind them in layers; this is especially true of some of the smaller coils which were very loosely wound.

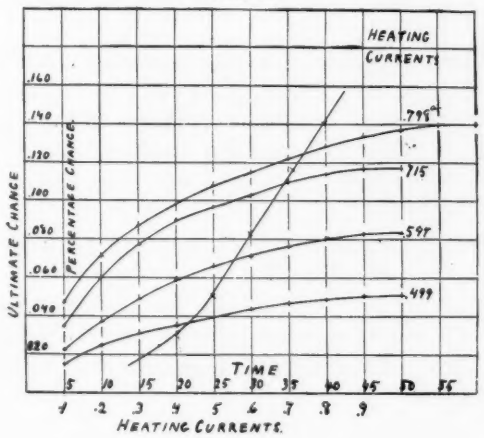
I hope shortly to be able to furnish more complete data which will avoid the necessity of winding the coils to a specified diameter. In addition to the tests on the bridge coils, measurements were made on one of the later forms of standard ohms as furnished by Elliot Brothers, C. L., No. 205. The results of these tests are given in Plot XV.

PLOT I.



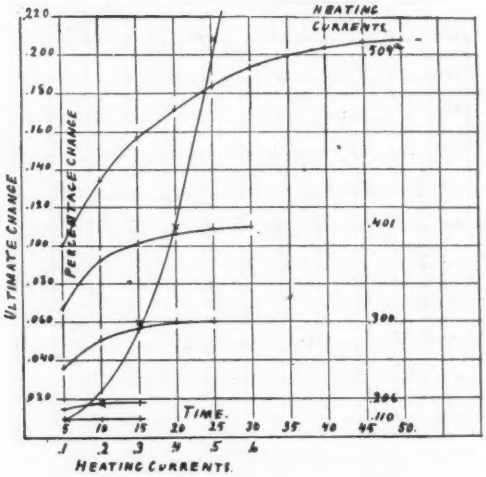
One-ohm coil in rheostat.
No. 18 B. & S. gage German silver wire.
Diameter of core 1.0 cm.; same for all coils.
One layer + of wire.
Resistance per linear centimeter 0.15 ohm.

PLOT II.



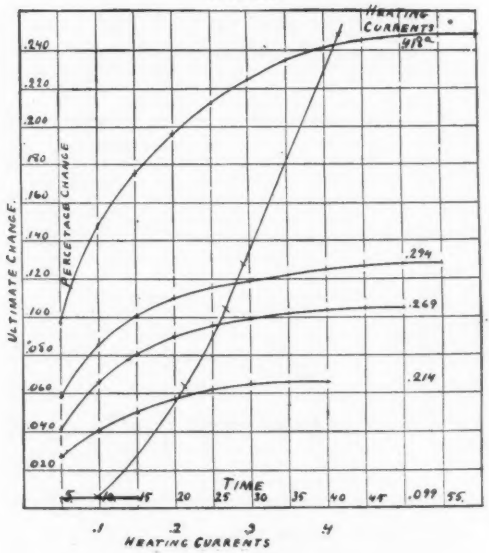
One-ohm coil in balance arm.
Composed of two 2-ohm coils in parallel.
No. 16 B. & S. gage German silver wire.
Diameter of coils 2.3 centimeters.
Resistance of each coil per linear centimeter 0.33 ohm.

PLOT III.



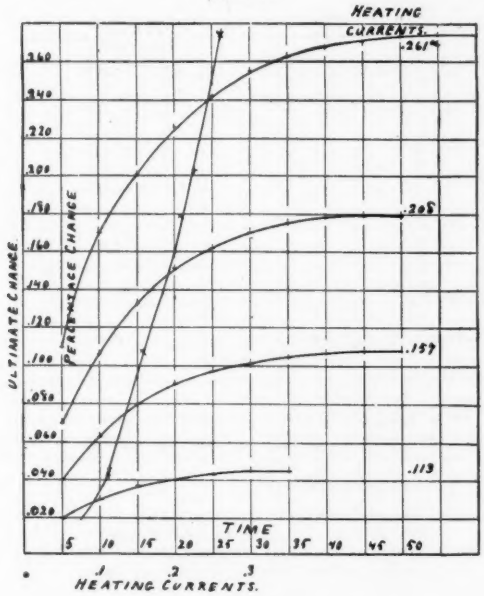
Two-ohm coil.
No. 18 B. & S. gage German silver wire.
Diameter of coil 1.5 centimeters.
Resistance per linear centimeter 0.29 ohm.

PLOT IV.



Five-ohm coil.
No. 18 B. & S. gage German silver wire.
Diameter of coil 2.2 centimeters.
Resistance per linear centimeter 0.69 ohm.

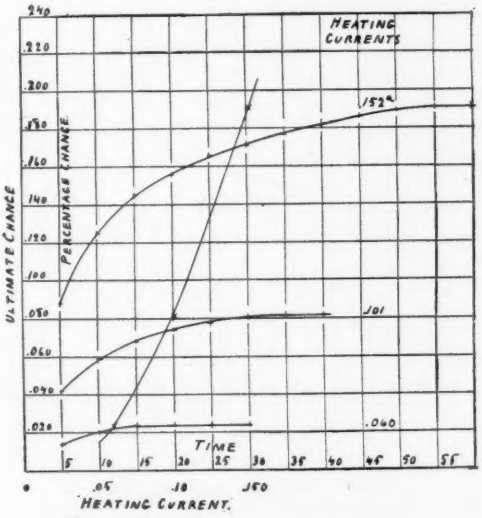
PLOT V.



Ten-ohm coils.
No. 20 B. & S. gage German silver wire.
Diameter of coil 2.1 centimeters.
Resistance per linear centimeter 1.3 ohms.

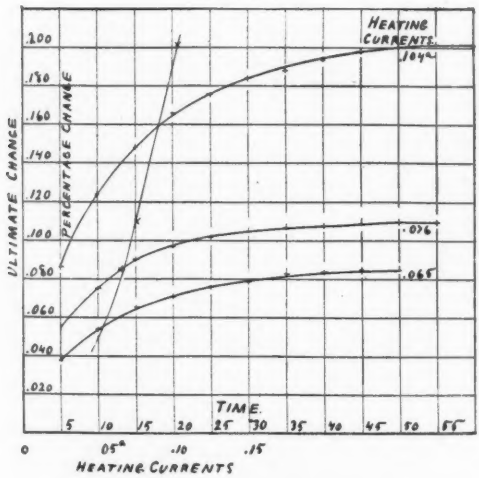
Points marked + on the ultimate change curve are from the coil in the balance arm.

PLOT VI.



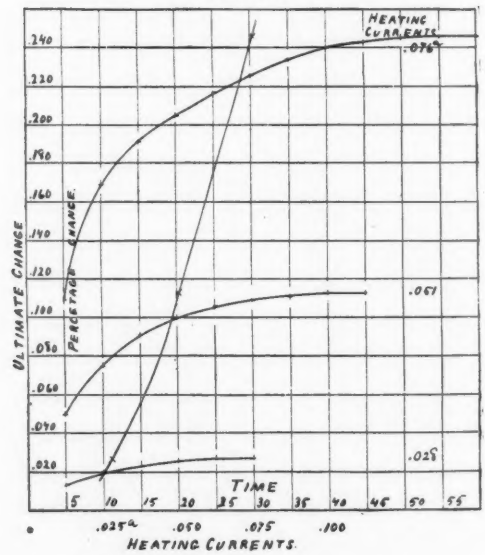
Twenty-ohm coil.
No. 22 B. & S. gage German silver wire.
Diameter of coil 1.9 centimeters.
Resistance per linear centimeter 2.7 ohms.

PLOT VII.



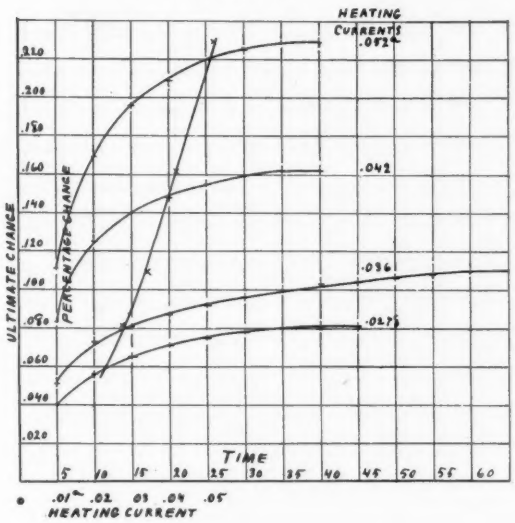
Fifty-ohm coil.
No. 24 B. & S. gage German silver wire.
Diameter of coil 2 centimeters.
Resistance per linear centimeter 7.1 ohms.

PLOT VIII.



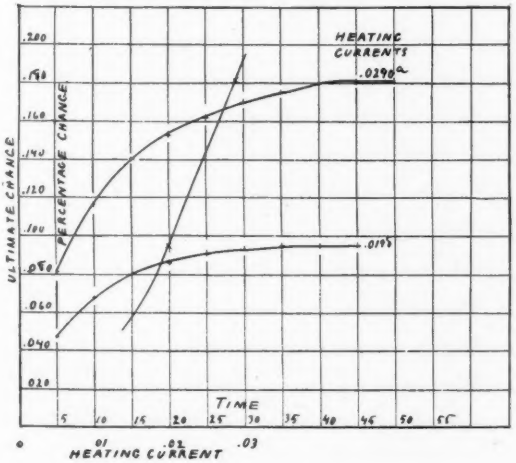
One hundred ohm coil.
No. 26 B. & S. gage German silver wire.
Diameter of coil 1.8 centimeters.
Resistance per linear centimeter 13 ohms.

PLOT IX.



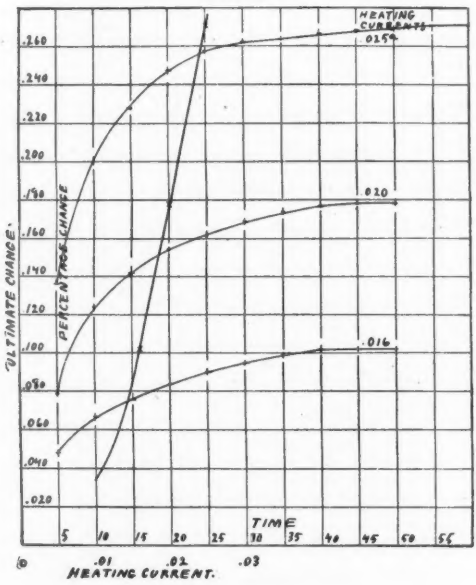
Two hundred ohm coil.
No. 28 B. & S. gage German silver wire.
Diameter of coil 1.6 centimeters.
Resistance per linear centimeter 27 ohms.

PLOT X.



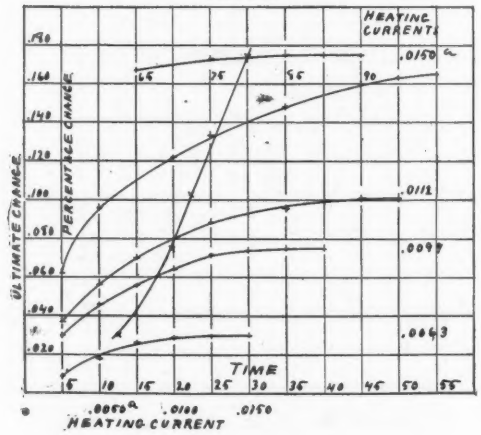
Five hundred ohm coil.
No. 30 B. & S. gage German silver wire.
Diameter of coil 1.8 centimeters.
Resistance per linear centimeter 67 ohms.

PLOT XI.



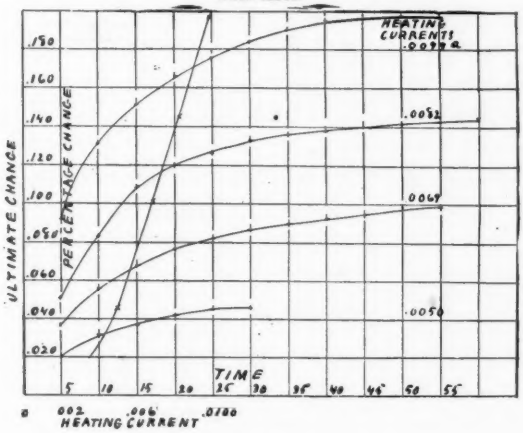
One thousand ohm coil.
No. 32 B. & S. gage German silver wire.
Diameter of coil 1.7 centimeters.
Resistance per linear centimeter 134 ohms.

PLOT XII.



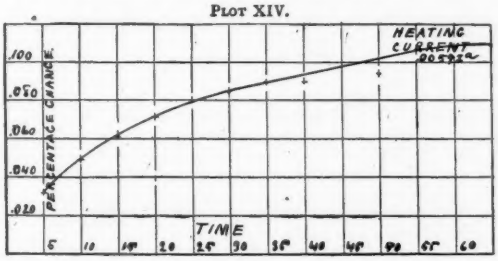
Two thousand ohm coil.
No. 32 B. & S. gage German silver wire.
Diameter of coil 2.1 centimeters.
Resistance per linear centimeter 273 ohms.

PLOT XIII.



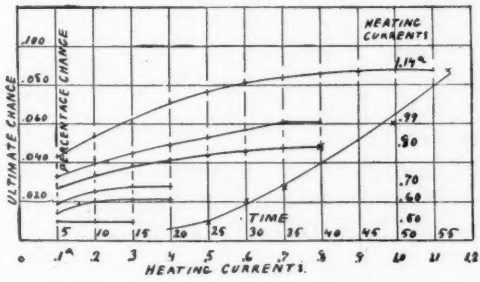
Five thousand ohm coil.
No. 34 B. & S. gage German silver wire.
Diameter of coil 2.1 centimeters.
Resistance per linear centimeter 694 ohms.

PLOT XIV.



Ten thousand ohm coil.
No. 34 B. & S. gage German silver wire.
Diameter of coil 2.7 centimeters.
Resistance per linear centimeter 1330 ohms.

PLOT XV.



Standard Ohm C. L., No. 205.
(Coil in flattened receptacle, tested in cooling bath.)

ROGERS LABORATORY OF PHYSICS,
MASSACHUSETTS INSTITUTE OF TECHNOLOGY.
January, 1897.

RESULTS OF TESTS MADE IN THE ENGINEERING LABORATORIES.

VII.

Received May 20, 1897.

Applied Mechanics.

Timber Trusses.

Tests of the Strength of Ten Triangular Trusses of Yellow Pine.

The rafters, and the tie of one (No. 494) of the trusses were each 8″ x 10″ in section, while the rafters and ties of the other nine were each about 6″ x 8″ in section. These nine trusses may be classified, according to the style of framing joint used, into three series, A, B, and C.

Series A consisted of two trusses (Nos. 519 and 533), the inclination of the rafters to the tie being 30° in each.

Series B consisted of three trusses (Nos. 520, 522, and 535), the inclination of the rafters to the tie being 45° in No. 522, and 30° in each of the others.

Series C consisted of four trusses (Nos. 517, 518, 523, and 524), the inclination of the rafters to the tie being 30° in Nos. 517 and 518, and 45° in Nos. 523 and 524.

The detailed dimensions and the style of each joint are shown in the accompanying cuts, and the manner of failure in each case is shown in the photographs of the fractures. In every case the load was applied at the top of the truss, and, except in No. 535, the supports were directly below the intersections of the center lines of the rafters with the center line of the tie.

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Inasmuch as the results of these tests do not furnish sufficient data to determine completely the distribution of the stresses in the different members, and as more tests are needed to show even the line of direction of the stress in each rafter, which is, probably, not coincident with the center line of each rafter, it seemed best to figure at present only a few of the stresses, stating the assumptions on which this figuring is based, and bearing in mind that these assumptions may be proved true or false by future experiments.

There are given in each case the total breaking load, the manner of failure, the load causing the second failure (for, in all cases, after certain portions had given away, certain other fastenings came into action), the manner of the second failure; and, in most cases, the shearing resistance per square inch of the timber under the first breaking load (the maximum in the majority of cases). This shearing resistance is figured on the assumptions, 1, that the resultant of the stress in each rafter acts along the center line of the rafter; 2, that the shearing resistance is uniformly distributed over the area sheared; and 3, that the additional fastenings (bolts or straps) did not act until the shearing resistance had been overcome.

Whatever may be shown to be true by future experiments in regard to the first and second assumptions, the behavior of the trusses under test would seem to show that the third is either true in all cases, or at least in most cases.

YELLOW PINE TRUSS, No. 494. Figures 1–4.

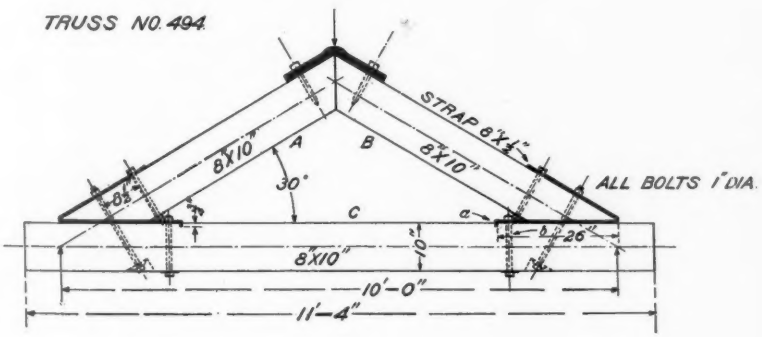

FIG. 1.

At a load of 68,000 pounds the iron began to draw out of the wood at the point marked *a*.

The loading was continued till a maximum was reached at 106,000 pounds.

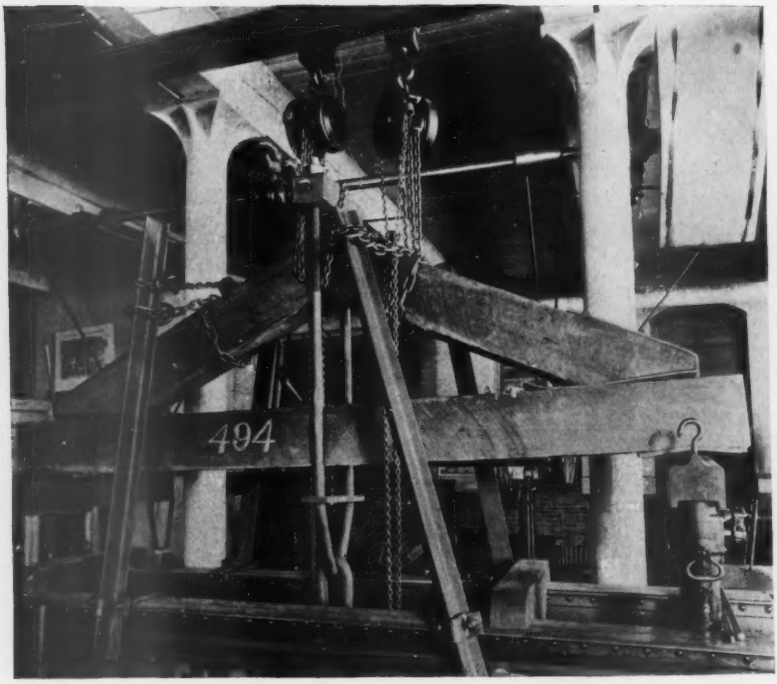

FIG. 2.

For some time before complete failure the bolts had been shearing through the tie; finally the bolt marked (*b*) broke by tension and bending.

Maximum compression per square inch in rafters	1,300 lbs.
Maximum tension per square inch in tie	1,150 lbs.

FIG. 3.

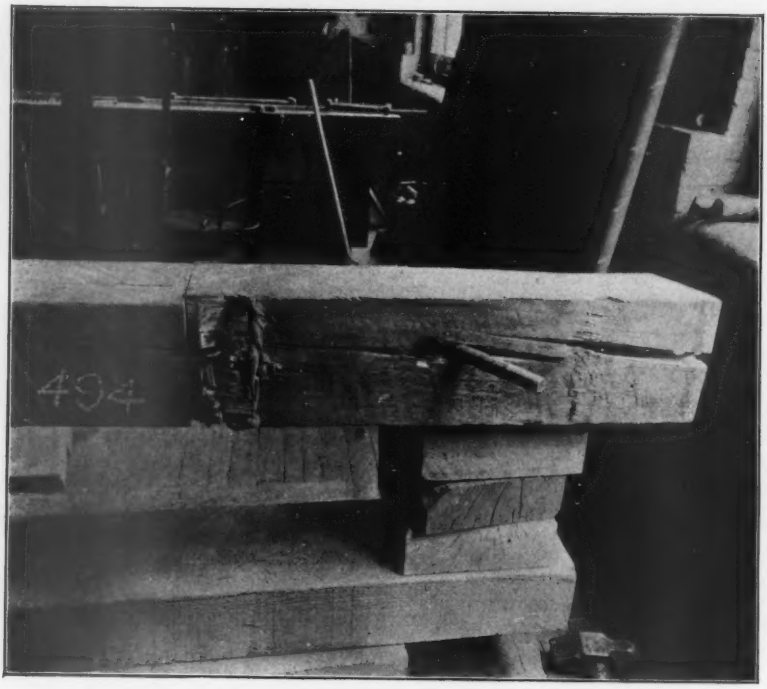

FIG. 4.

HARD PINE TRUSS, No. 519. SERIES A. Figures 5 and 6.

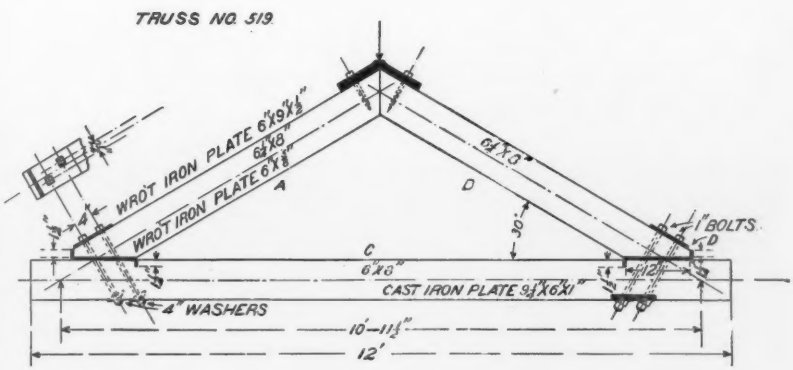

FIG. 5.

In this test downward deflections of the tie were noted for each 5,000 pounds increase of load.

Load.	Deflection.	Load.	Deflection.
5,000	....	35,000	....
10,000	.024″	40,000	.021″
15,000	.019″	45,000	.021″
20,000	.016″	50,000	.027″
25,000	.016″	55,000	.033″
30,000	.017″	60,000	.035″
35,000	.018″	65,000	.045″

The maximum load was . . . . . 80,000 lbs.
Maximum compression per square inch in rafters . . . . . 1,600 lbs.
Maximum tension per square inch in tie . . . . . 1,390 lbs.

The truss failed by the crushing of the foot of the rafter where it bore against the vertical lip of the iron shoe, and by the breaking of the through bolts. The cut does not show the manner of failure very clearly.

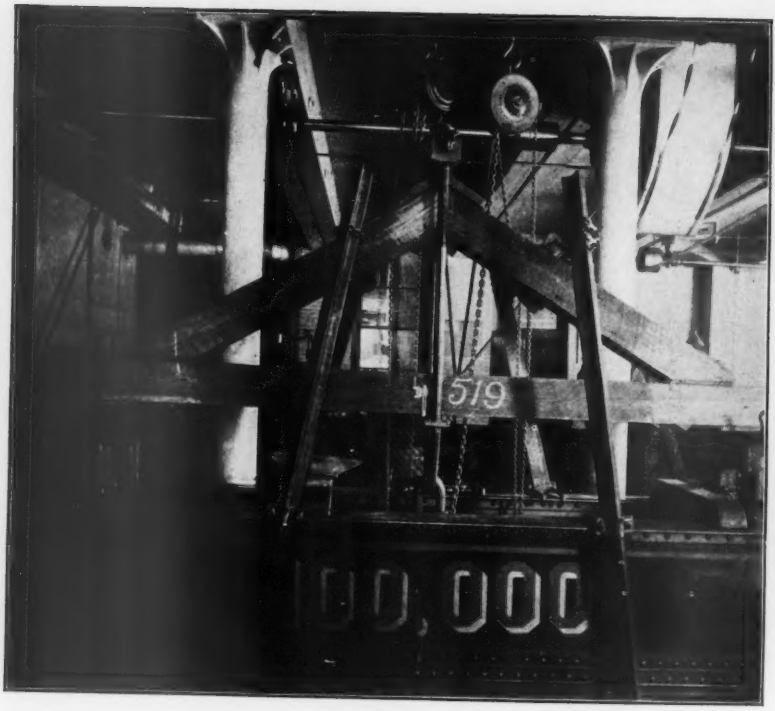

FIG. 6.

HARD PINE TRUSS, No. 533. SERIES A. Figures 7 and 8.

FIG. 7.

This truss is practically the same as that shown by the cut of No. 519. The total length of the bottom tie is $\frac{3}{4}''$ greater than in 519, and the distance between the supports is $1''$ less than in 519. The supports were placed at the intersection of the center lines through the members.

The maximum load on truss was	82,900 lbs.
Maximum compression per square inch in rafters	1,730 lbs.
Maximum tension per square inch in tie	1,500 lbs.

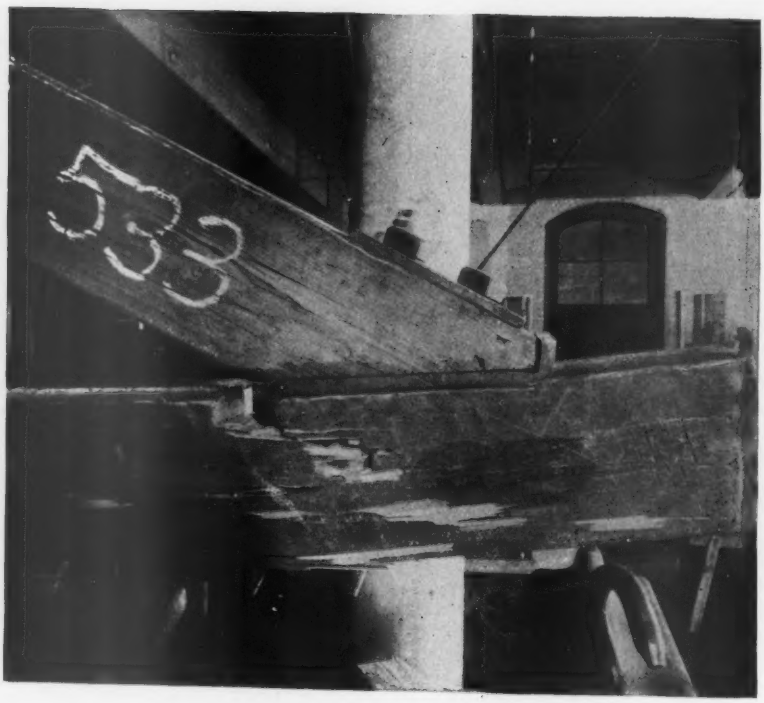

FIG. 8.

HARD PINE TRUSS, No. 520. SERIES B. Figures 9–11.

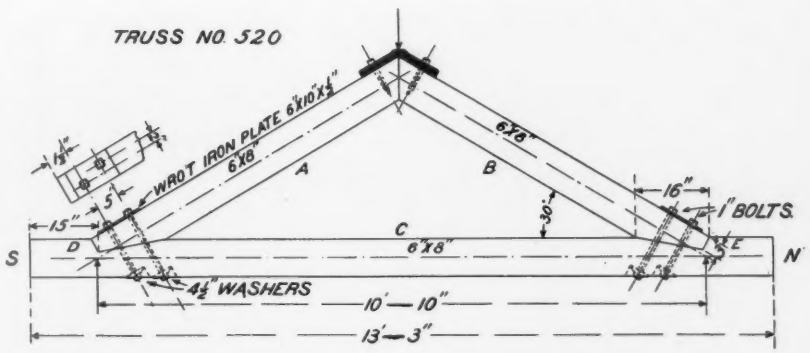

FIG. 9.

At a load of 48,400 pounds the tie sheared at *D*.

At a load of 49,255 pounds the tie sheared at *E*.

At a load of 53,625 pounds the inner bolt at *N* end broke. The outer bolt at this end gave way at a load of 47,085 pounds on the truss.

Maximum compression per square inch in rafters	1,130 lbs.
Maximum tension per square inch in tie	980 lbs.
Neglecting bolts, the maximum shear per square inch at end *D* . .	470 lbs.
Neglecting bolts, the maximum shear per square inch at end *E* . .	480 lbs.

FIG. 10. North end.

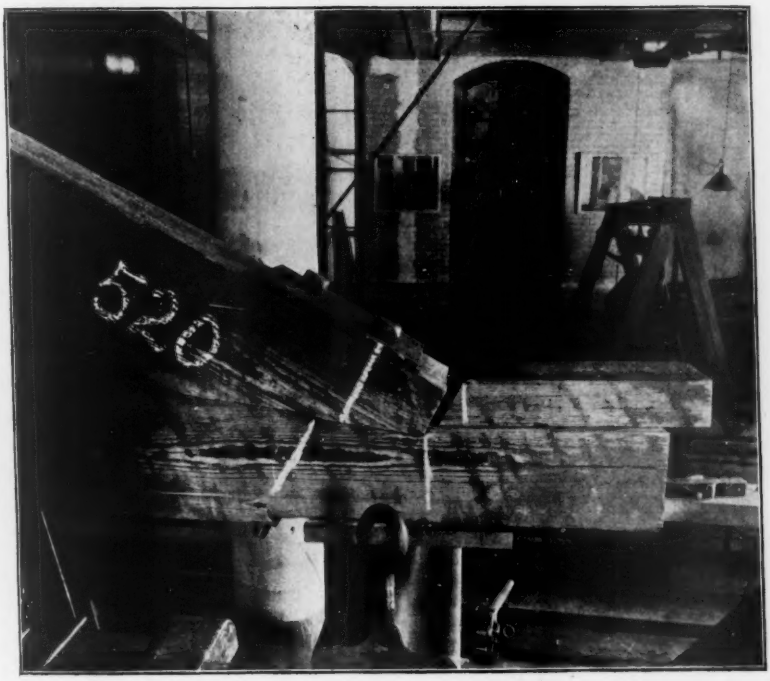

FIG. 11. South end.

HARD PINE TRUSS NO. 522. SERIES B. Figures 12–15.

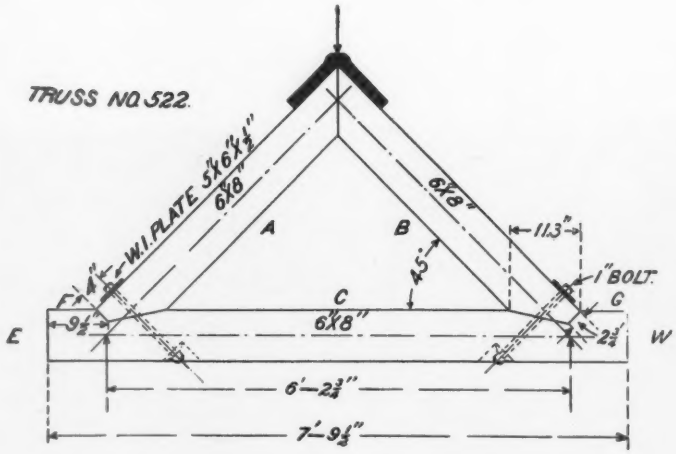

FIG. 12.

At a load of 102,300 pounds the tie sheared at *W* end. The tie then cracked by tension at this end, where the section was reduced by the recess made to take iron washer.

At 105,800 the east end of the tie sheared, and the bolt at this end gave way.

Maximum compression per square inch in rafters	1,560 lbs.
Maximum tension per square inch in tie	1,100 lbs.
Neglecting bolts, shearing force per square inch at time tie sheared at *W* end	900 lbs.
Neglecting bolts, shearing force per square inch at time tie sheared at *E* end	930 lbs.

FIG. 13.

FIG. 14.

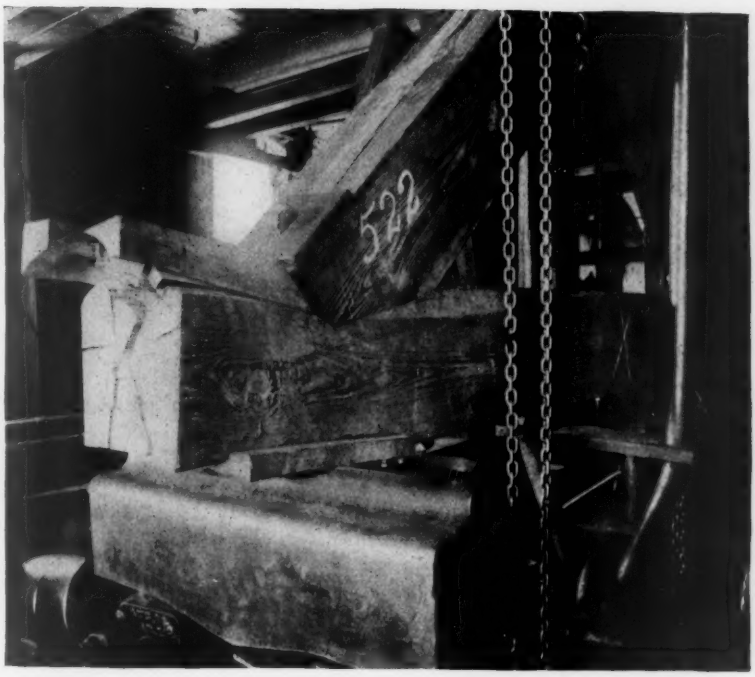

FIG. 15.

HARD PINE TRUSS No. 535. SERIES B. Figures 16 and 17.

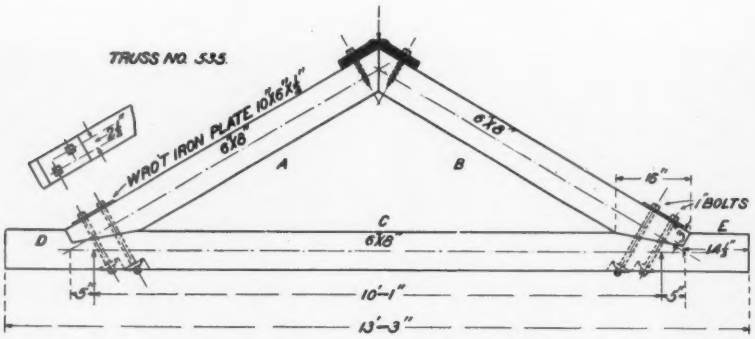

FIG. 16.

At a load of 47,900 pounds tie sheared at end marked *D*.
At 56,600 pounds both bolts at this end gave way.

Maximum compression per square inch in rafters	1,180 lbs.
Maximum tension per square inch in tie	1,020 lbs.
Neglecting bolts, maximum shear per square inch at *D* at time of shear	480 lbs.

It will be noticed that the supports were not at the intersection of the center lines of the members.

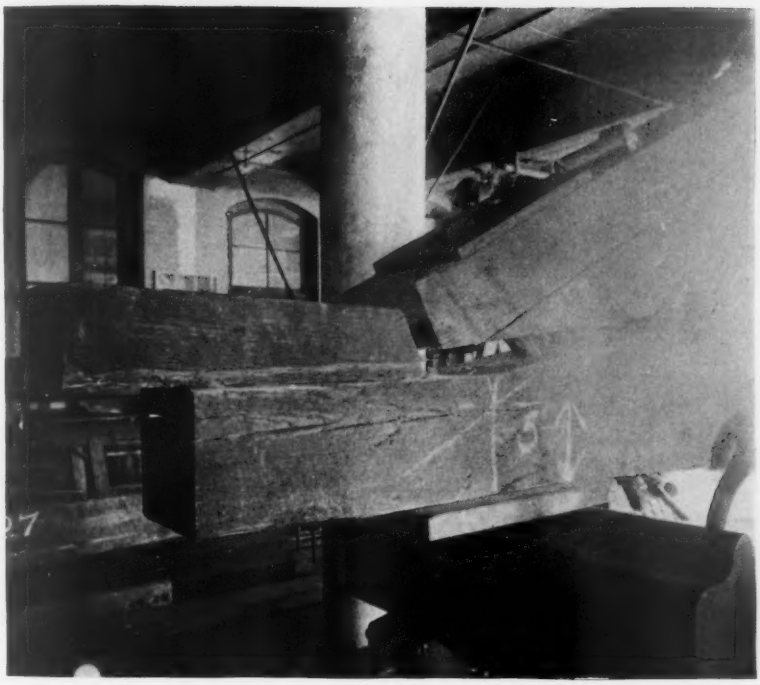

FIG. 17. Truss No. 535.

HARD PINE TRUSS, No. 517. SERIES C. Figures 18 and 19.

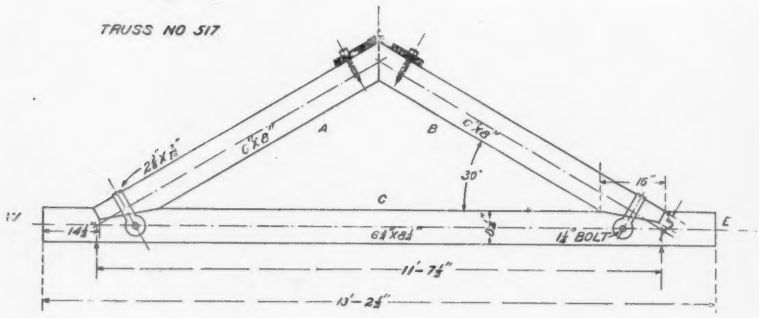

FIG. 18.

At a load of 56,700 pounds tie sheared at *E* end, causing load to drop off considerably. The loading was continued till at 37,650 pounds the strap at the *E* end gave way at both corners.

Maximum compression per square inch in rafters	1,180 lbs.
Maximum tension per square inch in tie	1,049 lbs.
Neglecting strap, maximum shear per square inch in tie at time of shear	570 lbs.

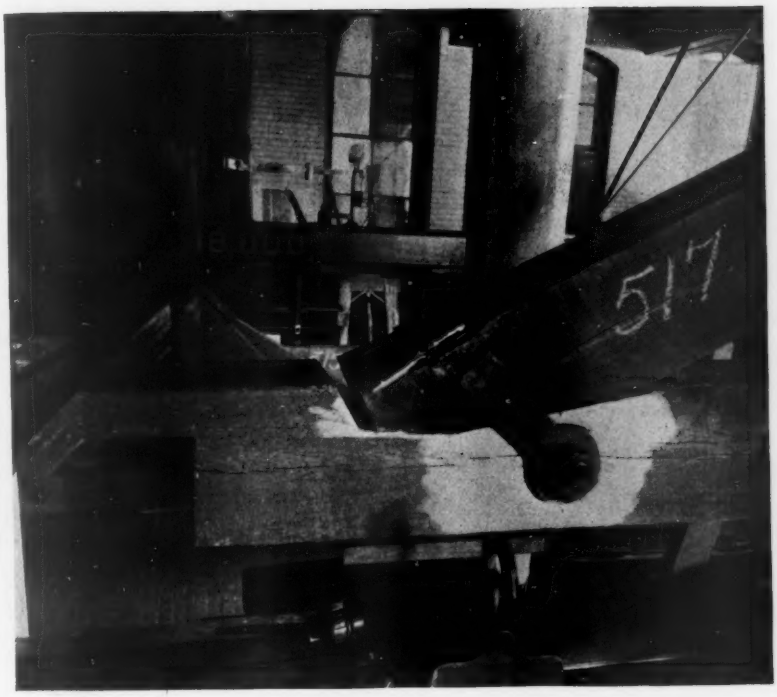

FIG. 19.

HARD PINE TRUSS, No. 518. SERIES C. Figure 20.

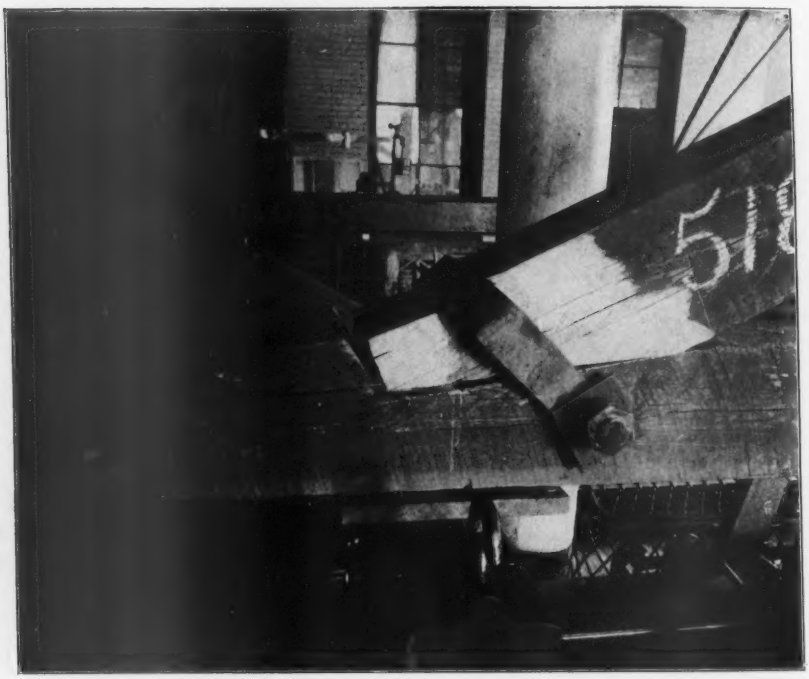

FIG. 20. Truss No. 518.

This truss was an exact duplicate of No. 517.

At a load of 55,800 pounds the tie sheared at *E* end, as in No. 517. The loading was continued after this shear, but did not again reach 55,800 pounds. At 49,300 the strap at the end which had sheared gave way at one corner.

Maximum compression per square inch in rafters	1,160 lbs.
Maximum tension per square inch in tie	1,010 lbs.
Neglecting strap, maximum shear per square inch in tie at time of shearing	540 lbs

HARD PINE TRUSS, No. 523. SERIES C. Figures 21–24.

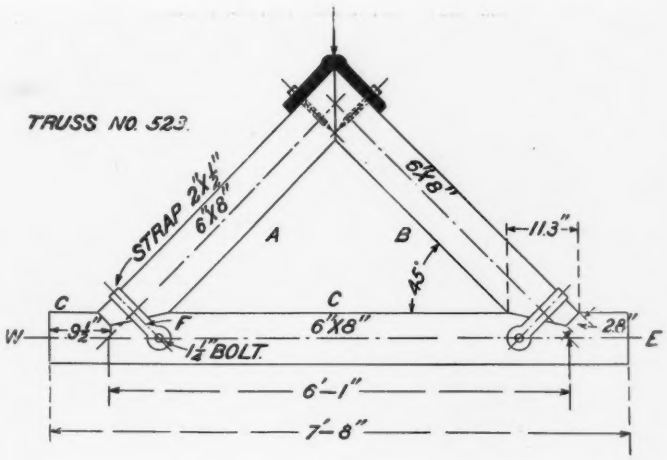

FIG. 21.

At a load of 93,600 pounds tie sheared at *C*. After the shear, continued loading till the strap at this end gave way at 79,200 pounds.

Maximum compression per square inch in rafters	1,380 lbs.
Maximum tension per square inch in tie	900 lbs.
Neglecting strap maximum shear per square inch in tie at time of shearing	820 lbs.

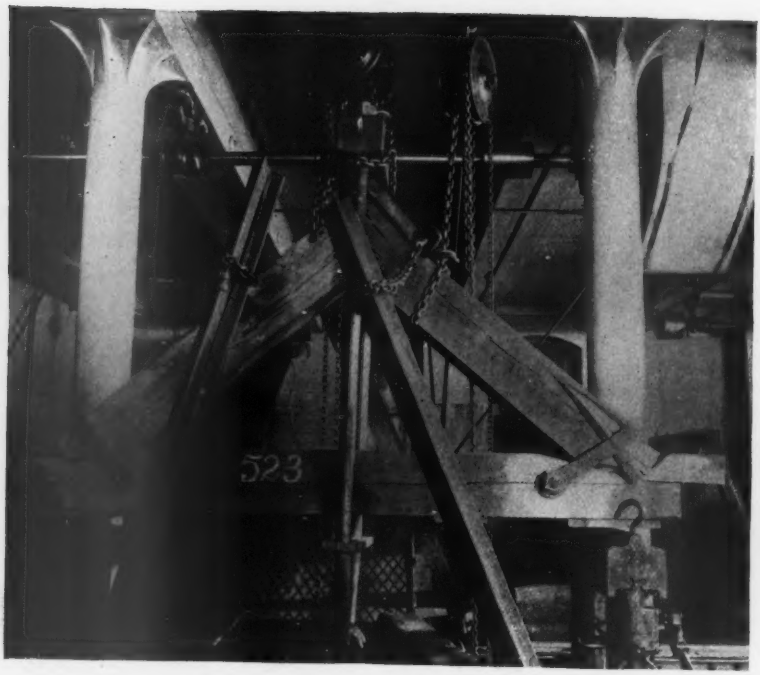

FIG. 22.

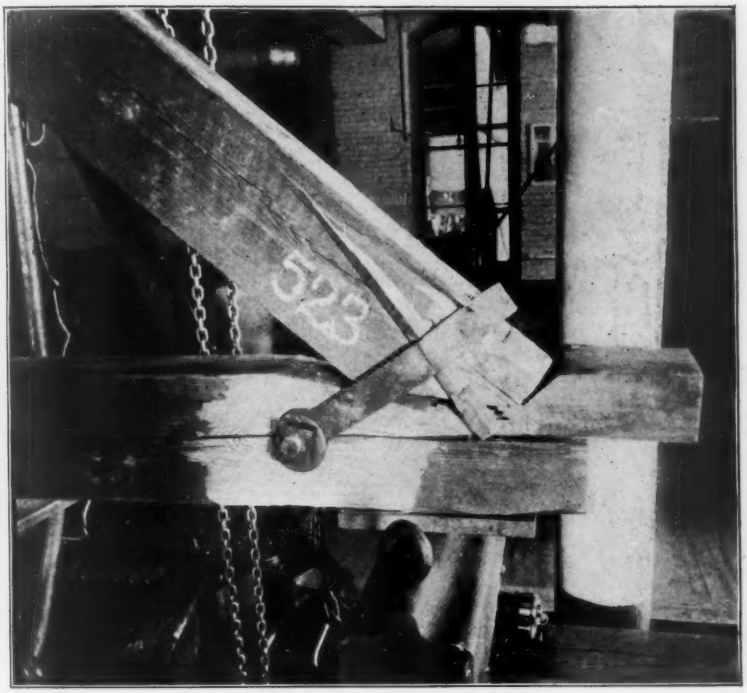

FIG. 23.

FIG. 24.

HARD PINE TRUSS, No. 524. SERIES C. Figures 25 and 26.

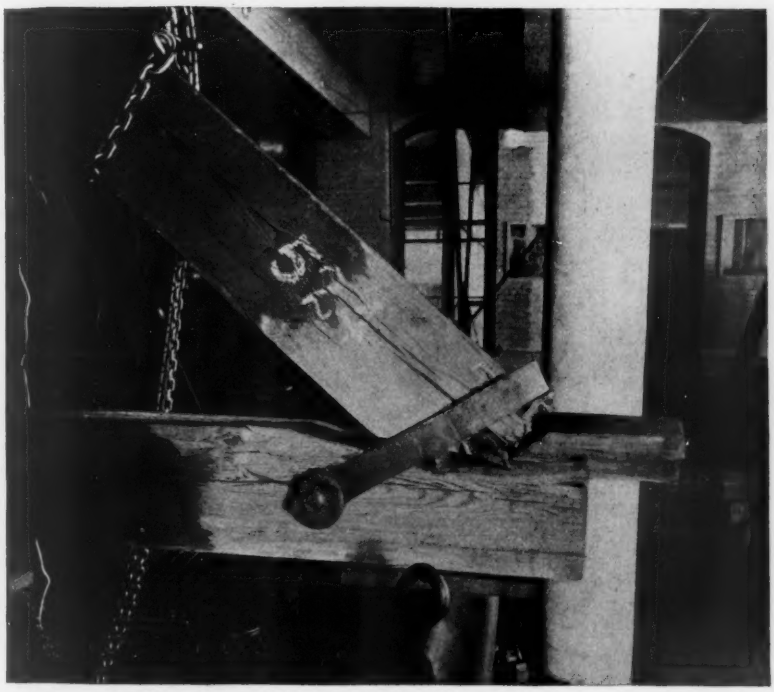

FIG. 25.

This truss was exactly the same as truss No. 523. At a load of 105,900 pounds tie sheared at *W* end. After shear, continued loading till strap at *W* end gave way at 87,100 pounds.

Maximum compression per square inch in rafters	1,560 lbs.
Maximum tension per square inch in tie	1,100 lbs.
Maximum shear per square inch in tie at time of shear	930 lbs.

FIG. 26.

Tests of Hard Pine Timber Headers.

The object of this investigation was to find the strength of timber headers loaded through tail-beams framed into the headers by tusk and tenon joints.

As the test was to be one of the headers and not of the tail-beams, these were made quite short. In some of the tests the headers were framed to the trimmers by a double tenon, and held by a joint bolt; in others the headers were held by a stirrup iron and joint bolt.

I beams were used to distribute the load equally between the tail-beams. The upward pull on the top I beam was taken by the weighing system of the testing machine. By screwing up the jacks on which the trimmers rested, loads were applied. The tusk and tenon joints were all the same as those shown by Figure *27a*.

Cuts of Nos. 482, 483, 484, 490, and 500 show the arrangement by means of which the loads were distributed between the tail-beams.

HARD PINE FRAMED HEADERS, No. 482. Figures 27 and 28.

Size of header 6″ x 12″, 6′–8″ long. Number of tail-beams, (4) 16″ on centers.

At a load of 30,380 pounds the north header gave way, starting at the lower tenon at the trimmer on east side (see Fig. 28).

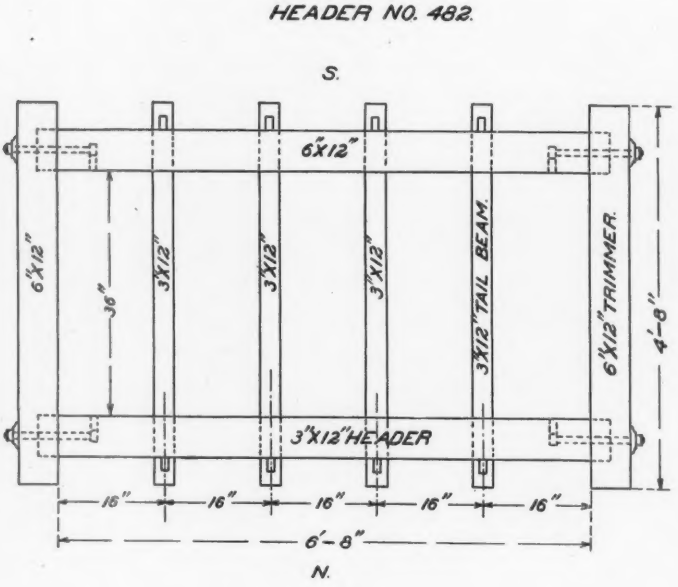

FIG. 27.

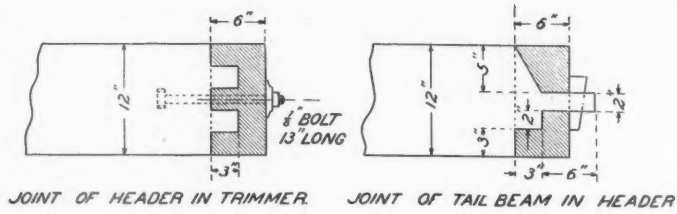

FIG. 27a.

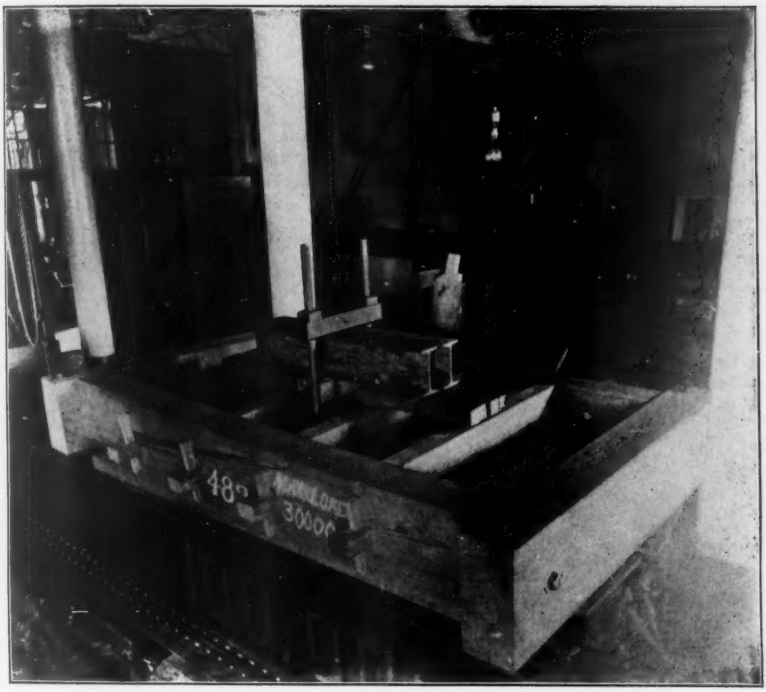

FIG. 28.

HARD PINE FRAMED HEADERS, No. 483. Figure 29.

FIG. 29.

The frame of this header was the same as No. 482, with broken north header and west tail-beam replaced by sound sticks. At 40,380 the north header gave way, failing as in the previous joint.

HARD PINE FRAMED HEADER, No. 484. Figure 30.

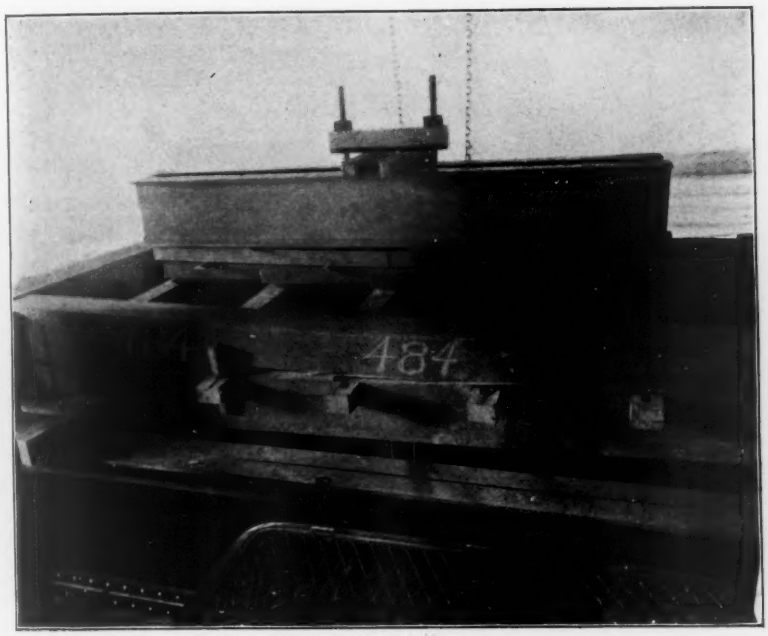

FIG. 30.

Five tail-beams 16″ centers used in this case. Header 6″ x 12″, 8′ – 0″ long. Failed at south header at load of 29,740 pounds.

HARD PINE FRAMED HEADERS, No. 485. Figure 31.

FIG. 31.

This was an exact duplicate of No. 484. Failed at north header at a load of 31,300 pounds on scales, making, including the weights of the I beams used for loading, 32,090 pounds.

HARD PINE FRAMED HEADERS, No. 486. Figure 32.

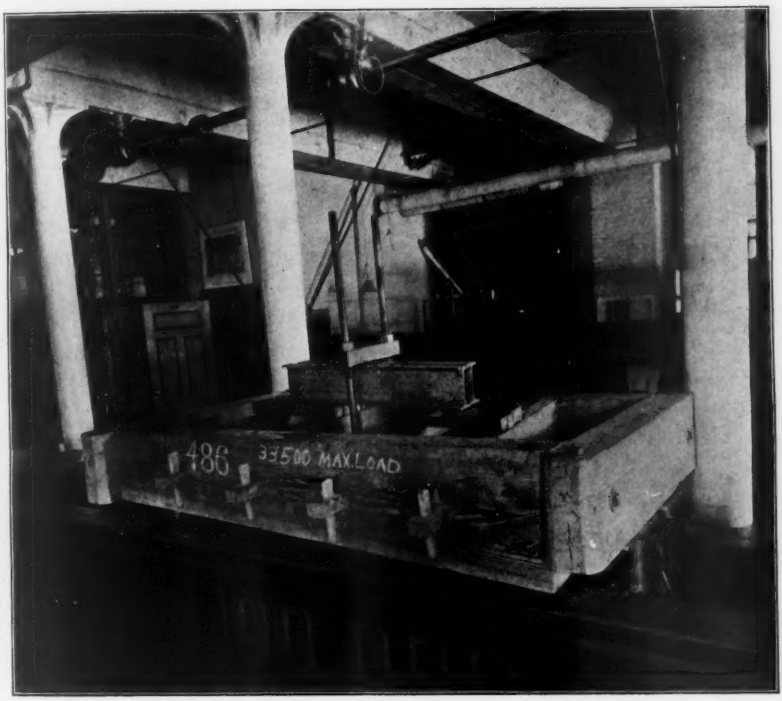

FIG. 32.

Same general frame as No. 483, with north header of 483 replaced by sound stick. At 33,500 pounds on scales or 33,850 on tail-beams, the north header gave way.

HARD PINE TIMBER HEADERS, No. 487. Figure 33.

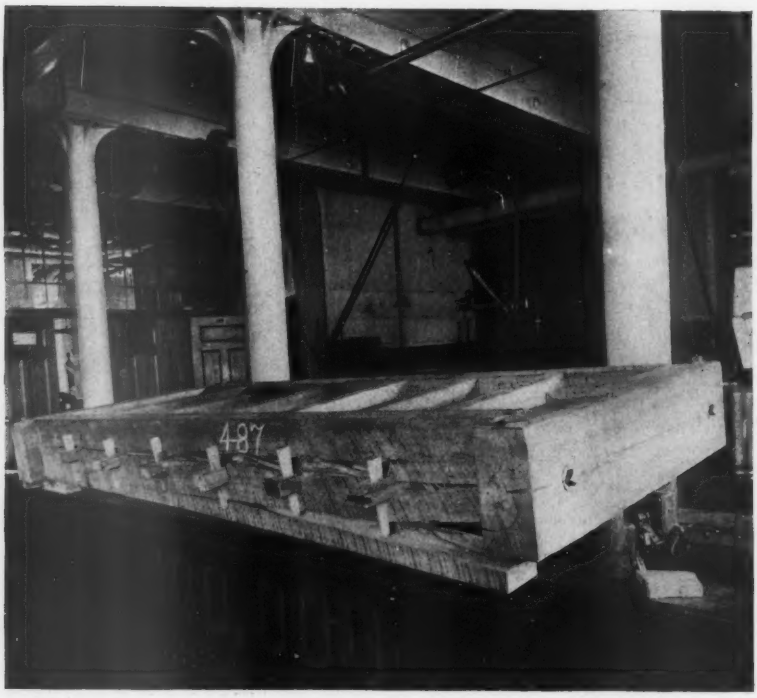

FIG. 33.

Headers were 6″ x 12″ 9′ – 4″ long. There were six tail-beams spaced 16″ on centers. The load was distributed by an arrangement of the I beams similar to that shown in the cut of No. 493.

At a load of 37,220 pounds, the south header failed throughout its entire length.

HARD PINE TIMBER HEADERS, No. 490. Figures 34 and 35.

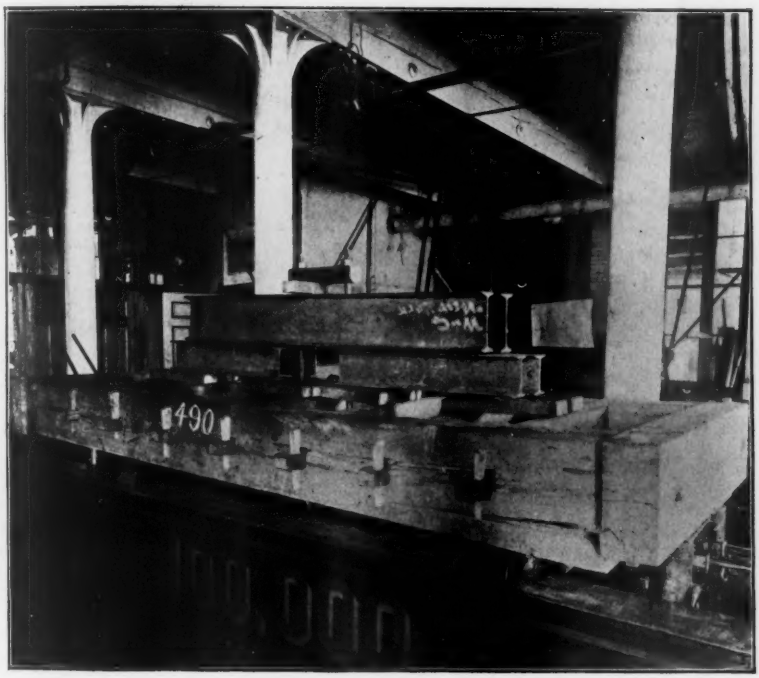

FIG. 34. North.

Headers were 6″ x 12″, 10′ – 8″ long. There were seven tail-beams spaced 16″ centers. At 27,810 pounds the north header failed, followed almost immediately by the south header.

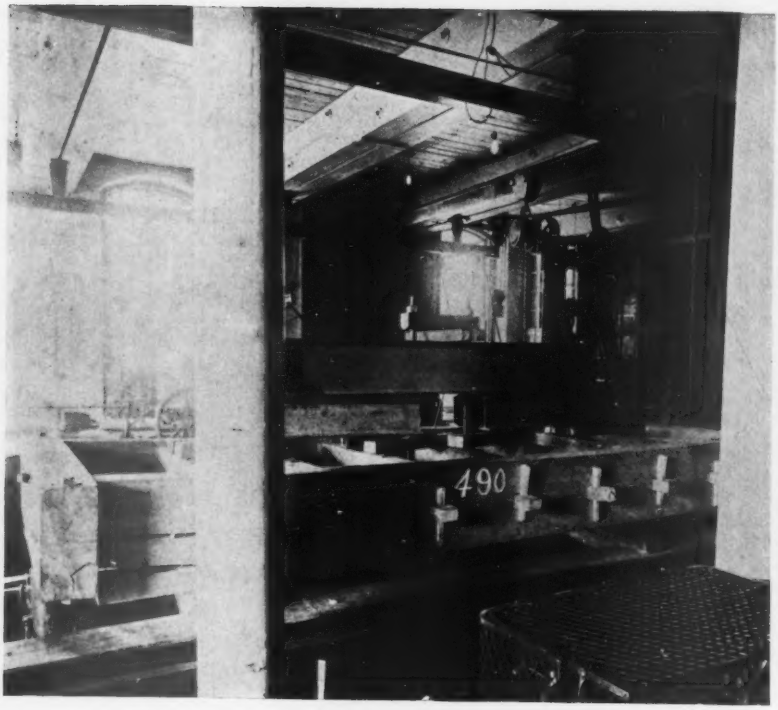

FIG. 35. South.

HARD PINE TIMBER HEADERS, No. 492. Figures 36 and 37

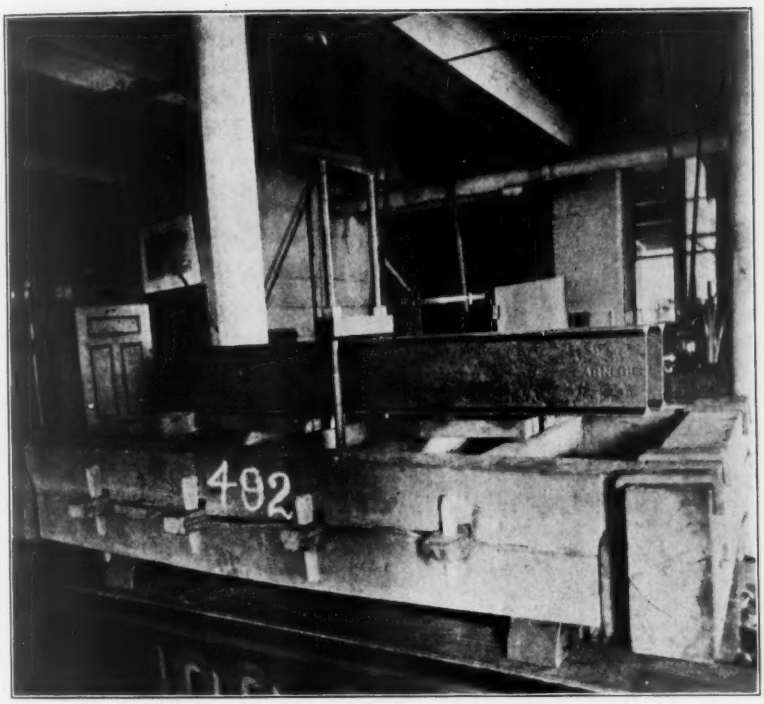

FIG. 36. North.

Headers Nos. 492, 493, and 500 were held to the trimmers by stirrup irons instead of by double tenons and joint bolts. Header No. 492 was of the same general dimensions as Nos. 483 and 486. The headers were 6″ x 12″, 6′ – 8″ long.

There were four tail-beams 16″ on centers. At 25,590 pounds the south header failed, soon followed by the north header.

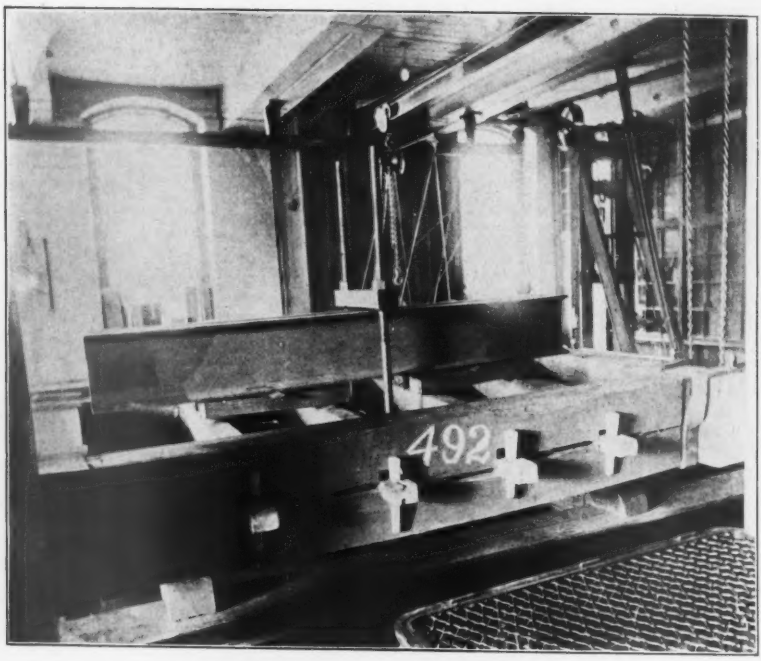

FIG. 37. South.

HARD PINE TIMBER HEADERS, No. 493. FIG. 38.

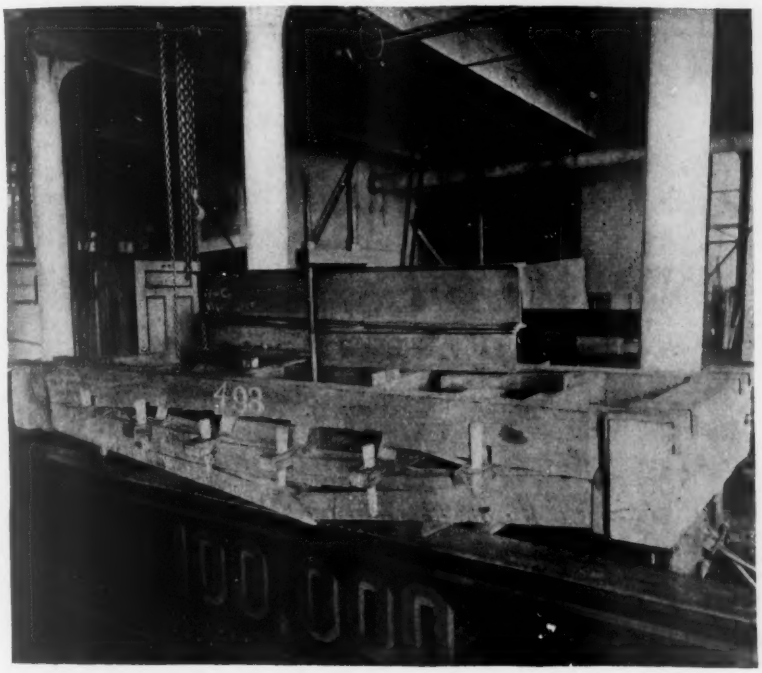

FIG. 38.

Same general dimensions as No. 487. Header 6″ x 12″, 9′ – 4″ long, held to trimmer by stirrup irons. At a load of 26,020 pounds, the north header failed completely.

HARD PINE TIMBER HEADERS, No. 500. FIG. 39.

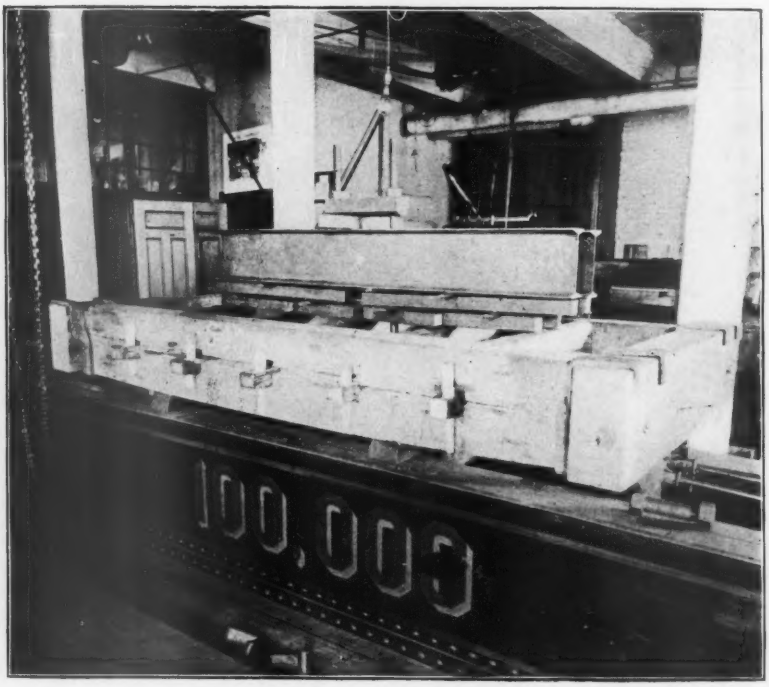

FIG. 39. Header No. 500.

Same general dimensions as Nos. 484 and 485. Headers were 6″ x 12″, 8′ – 0″ long, held to trimmers by stirrup irons. Five tail. beams spaced 16″ on centers. Maximum load at failure, 32,740 pounds. Failed at the north header as shown by the cut.

CAST IRON WATER PIPE.

Summary of Tests.

No. of test.	Size of pipe.	Average inside diameter.	Average length.	Average thickness.	Maximum load.	Maximum outside fiber stress calculated from maximum load, assuming each half of pipe as a beam fixed at the ends.	Remarks.
	Ins.	Ins.	Ins.	Ins.	Lbs.	Lbs. per sq. in.	
1	10	9.97	40	.54	19,000	12,800	Broke at A and A'.
2	12	11.96	42	.62	25,000	14,600	Broke at A and A'.
3	10	0.98	42	.54	22,500	14,500	Spigot end. Broke at A'.
4	48	48.14	29	1.14	18,100	17,800	Break started at A.
5	12	12.02	42½	.61	24,300	14,600	Spigot end. Break started at A'.
6	12	11.96	36½	.69	32,500	17,900	Spigot end. Broke at A.
7	10	9.93	36⅜	.64	41,000	21,600	Spigot end. Broke at A'.
8	16	16.00	36	.79	35,000	19,600	Broke at A.
9	16	16.06	35⅞	.80	35,700	19,700	Broke at A'.
10	16	16.06	35⅜	.75	35,300	22,300	Broke at A'.
11	20	19.88	37	.82	28,500	17,800	Broke at A.
12	20	19.91	36	.95	38,100	18,300	Broke at A'.
13	20	19.79	36⅜	.80	40,000	26,300	Broke at A'.
14	24	23.84	39½	.90	33,800	19,600	Broke at A'.
15	24	23.95	41½	.87	30,700	18,200	Broke at A.
16	24	23.89	40⅛	.90	33,600	19,200	Broke at A.
17	30	29.84	34½	1.15	36,300	18,700	Broke at A.
18	6	6.10	21½	.49	26,500	25,800	Broke at A.
19	8	7.96	20½	.58	27,700	26,000	Broke at A.
20	6	6.07	21½	.48	20,500	20,300	Broke at A and B.
21	8	7.94	21⅜	.59	27,900	23,700	Broke at A'.
22	6	6.08	22½	.50	25,800	23,000	Broke at A'.
23	8	7.90	21½	.63	30,100	22,600	Broke at A'.
24	6	6.09	21⅜	.49	27,000	26,000	Broke at A.
25	8	7.93	24½	.59	21,900	16,200	Broke at A.
26	6	6.09	36½	.49	38,700	21,600	Spigot end. Broke at A'.
27	8	7.89	36⅜	.62	40,300	18,300	Spigot end. Broke at B.
28	48	47.95	25	1.46	25,800	17,900	Spigot end. Broke at A.
29	36	36.05	34	1.07	24,200	17,300	Broke at A.
30	48	48.02	32½	1.43	32,300	18,200	Spigot end. Broke at A.
31	48	47.90	34	1.25	24,500	17,000	Spigot end. Broke at A'.

In tests Nos. 1, 2, 3, 4, 5, 6, 28 the load was applied on a space of 15″ in the middle of the length of the pipes. In remaining tests the load was applied on the entire length of the specimens. In all of the tests the loads were applied to the specimens through iron platforms. As these platforms were rigid, the load was applied along an element.

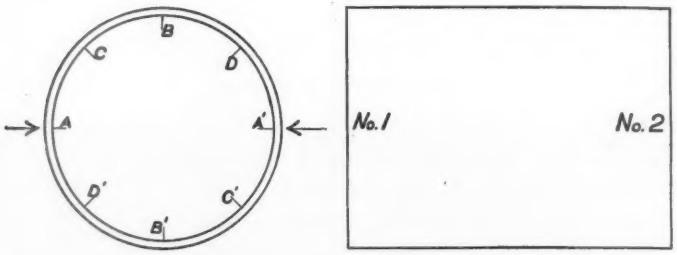

FIG. 40. DIAGRAMS OF CAST IRON WATER PIPE, TRANSVERSE AND LONGITUDINAL SECTIONS. The arrows indicate the direction of pressure; the letters *A A'*, *B B'*, etc., the diameters upon which the deflection was measured.

No. 4. TEST ON CAST IRON WATER PIPE.

March 14, 1897.

	Thickness.		Inside Diameter.		Length.
	End No. 1.		End No. 1.	End No. 2.	
A	1.20				29″
B	1.12	AA′	48.06	48.13	
C	1.19				
D	1.09	BB′	48.19	48.19	
A′	1.12				
B′	1.16				
C′	1.14				
D′	1.11				

Deflection Measurements.

Loads.	End No. 1.				End No. 2.				Average Difference.			
	AA′.	BB′.	CC′.	DD′.	AA′.	BB′.	CC′.	DD′.	AA′.	BB′.	CC′.	DD′.
0	1.08	1.00	.98	.97	.90	.96	.99	.99	.....	....	....	....
5,000	.87	1.24	1 01	1.01	.67	1.21	1.05	1.03	—.220	.245	.045	.040
10,000	.60	1.50	1.03	1.03	.44	1.42	1.05	1.04	—.250	.235	.010	.015
15,000	.26	1.80	1.06	1.04	.09	1.74	1.09	1.05	—.345	.310	.035	.010
18,100	Maximum load. Cracked along A′A′.											

Size of pipe	48″	Maximum outside fiber stress calculated	
Average inside diameter	48.14″	from maximum load, assuming each	
Average length	29″	half of pipe as a beam fixed at the	
Average thickness	1.14″	ends	17,800 lbs.

REMARKS.

Spigot end.
Load applied on space of 15″ along center of length.
Lip on End No. 2 about ¾″ wide and 1¼″ thick.
Nick at C End No. 1. Length at nick 28″. Length at A′A′ 29″.

No. 8. TEST ON CAST IRON WATER PIPE.

March 18, 1897.

	Thickness.		Inside Diameter.	Length.
	End No. 1.	End No. 2.		
A	.75	.74	16.00″	36″
B	.76	.73	.....	....
A′	.86	.83	.....	....
B′	.87	.81	.....	....

Deflection Measurements.

Loads.	End No. 1.		End No. 2.		Average Difference.	
	AA′.	BB′.	AA′.	BB′.	AA′.	BB′.
0	16.70	16.68	16.60	17.14	.....	....
5,000	16.67	16.71	16.60	17.13	—.015	.010
10,000	16.66	16.73	16.58	17.15	—.015	.020
15,000	16.65	16.76	16.56	17.17	—.015	.025
20,000	16.60	16.79	16.54	17.20	—.035	.030
25,000	16.58	16.81	16.51	17.20	—.025	.010
30,000	16 55	16.83	16.47	17.23	—.035	.025
35,000	Maximum load.		Break started at A, End No. 1, cracked nearly whole length of pipe. Second break started at A′A′ and B′B′ simultaneously.			

Size of pipe	16″	Maximum outside fiber stress calculated	
Average inside diameter	16.00″	from maximum load, assuming each	
Average length	36″	half of pipe as a beam fixed at the	
Average thickness	.79″	ends	19,600 lbs.

REMARKS.

Load applied along whole length of specimen.

No. 9. TEST ON CAST IRON WATER PIPE.

March 19, 1897.

	Thickness. End No. 1.	Inside Diameter.		Length.
A	.79	16.06	BB	35⅞″
B	.74	.....	B′B′	36″
A′	.79	.....		
B′	.87	.....		

Deflection Measurements.

Loads.	End No. 1.		End No. 2.		Average Difference.	
	AA′.	BB′.	AA′.	BB′.	AA′.	BB′.
0	16.74	16.84	16.49	16.41	.....	....
5,000	16.71	16.86	16.47	16.45	—.025	.030
10,000	16.69	16.90	16.42	16.46	—.035	.025
15,000	16.66	16 92	16.39	16.50	—.030	.030
20,000	16.63	16.94	16.39	16.51	—.015	.015
25,000	16.59	16.98	16.35	16.55	—.040	.040
35,700	Maximum Load. Cracked the whole length at A′A′; then broke at AA; then broke at B′B′; then broke at BB.					

Size of pipe	16″	Maximum outside fiber stress calculated	
Average inside diameter	16.06″	from maximum load, assuming each	
Average length	35⅞″	half of pipe as a beam fixed at the	
Average thickness	.80″	ends	19,700 lbs.

REMARKS.

Spigot end.
Load applied along whole length of specimen.
Lip on End No. 2 about ⅛″ wide and 1″ thick.

No. 10. TEST ON CAST IRON WATER PIPE.

March 20, 1897.

	Thickness.			Inside Diameter.		Length.
	End No. 1.	End No. 2.		End No. 1.	End No. 2.	
A	.71	.75				
B	.72	.73	AA′	16.11	16.08	35½″
A′	.77	.78				
B′	.81	.74	BB′	16.03	16.03	

Deflection Measurements.

Loads.	End No. 1.		End No. 2.		Average Difference.	
	AA′.	BB′.	AA′.	BB′.	AA′.	BB′.
0	16.74	17.00	16.74	16.44	.....	....
5,000	16.73	17 02	16.72	16.48	—.015	.030
10,000	16.70	17.05	16.68	16.50	—.035	.025
15,000	16 66	17.10	16.65	16.54	—.035	.045
20,000	16.62	17.12	16.62	16.56	—.035	.020
25,000	16.60	17.14	16.60	16.59	—.020	.025
30,000	16.56	17.18	16.56	16.61	—.040	.030
35,300	Maximum load. Broke along A′A′; then broke along AA.					

Size of pipe . . . . . 16″
Average inside diameter . . . . . 16.06″
Average length . . . . . 35½″
Average thickness . . . . . .75″

Maximum outside fiber stress calculated from maximum load, assuming each half of pipe as a beam fixed at the ends . . . . . 22,300 lbs.

REMARKS.

Load applied along whole length of specimen.

No. 11. TEST ON CAST IRON WATER PIPE.

March 22, 1897.

	Thickness.			Inside Diameter.			Length.
	End No. 1.	End No. 2.		End No. 1.	End No. 2.		
A	.81	.76				AA	37⅛″
B	.85	.84	AA′	19.89	19.86	BB	37⅛″
A′	.83	.84				AA′	36⅝″
B′	.85	.80	BB′	19.86	19.89	BB′	36⅝″

Deflection Measurements.

Loads.	End No. 1.		End No. 2.		Average Difference.	
	AA′.	BB′.	AA′.	BB′.	AA′.	BB′.
0	20.22	20.34	20.40	20.63	.....	...
5,000	20.20	20.38	20.34	20.68	—.040	.045
10,000	20.17	20.40	20.27	20.74	—.050	.040
15,000	20.12	20.45	20.14	20.81	—.090	.060
28,500	Maximum load. Broke at AA; then broke at A′A′.					
18,000		Broke at B′B′ and BB.				

Size of pipe . . . . . 20″
Average inside diameter . . . . . 19.88″
Average length . . . . . 37″
Average thickness . . . . . .82″

Maximum outside fiber stress calculated from maximum load, assuming each half of pipe as a beam fixed at the ends . . . . . 17,800 lbs.

REMARKS.

Load applied along whole length of specimen.

No. 12. TEST ON CAST IRON WATER PIPE.

March 23, 1897.

	Thickness.			Inside Diameter.			Length.
	End No. 1.	End No. 2.		End No. 1.	End No. 2.		
A	1.00	1.01	AA′	19.91	19.95	AA	36″
B	.96	.94				BB	35⅞″
A′	.93	.90	BB′	19.88	19.92	A′A′	36⅛″
B′	.97	.90				B′B′	36⅛″

Deflection Measurements.

Loads.	End No. 1.		End No. 2.		Average Difference.	
	AA′.	BB′.	AA′.	BB′.	AA′.	BB′.
0	20.13	20.57	20.20	20.54	.....	....
5,000	20.10	20.58	20.18	20.57	—.025	.020
10,000	20.06	20.62	20.14	20.59	—.040	.030
15,000	20.03	20.65	20.12	20.61	—.025	.025
20,000	20.00	20.67	20.09	20.63	—.030	.020
38,100	Maximum load. Broke on A′A′. Second break on AA and BB.					

Size of pipe . . . . . 20″
Average inside diameter . . . . . 19.91″
Average length . . . . . 36″
Average thickness . . . . . .95″

Maximum outside fiber stress calculated from maximum load, assuming each half of pipe as a beam fixed at the ends . . . . . 18,300 lbs.

REMARKS.

Load applied along whole length of specimen.

No. 13. TEST ON CAST IRON WATER PIPE.

March 24, 1897.

	Thickness.			Inside Diameter.			Length.
	End No. 1.	End No. 2.		End No. 1.	End No. 2.		
A	.81	.83	AA′	19.75	19.80	AA	36⅜″
B	.81	.76				BB	36⅜″
A′	.85	.73	BB′	19.80	19.80	A′A′	37⅛″
B′	.80	.78				B′B′	37″

Deflection Measurements.

Loads.	End No. 1.		End No. 2.		Average Difference.	
	AA′.	BB′.	AA′.	BB′.	AA′.	BB′.
0	20.88	20.55	20.23	20.75	.....	....
5,000	20.84	20.58	20.20	20.76	—.035	.020
10,000	20.79	20.61	20.16	20.80	—.045	.035
15,000	20.76	20.65	20.12	20.83	—.035	.035
20,000	20.72	20.69	20.09	20.87	—.035	.040
40,000	Maximum load. Broke at A′A′; next broke at AA.					
26,800	Broke at BB.					

Size of pipe . . . . . 20″
Average inside diameter . . . . . 19.79″
Average length . . . . . 36⅜″
Average thickness . . . . . .80″

Maximum outside fiber stress calculated from maximum load, assuming each half of pipe as a beam fixed at the ends . . . . . 26,300 lbs.

REMARKS.

Load applied along whole length of specimen.

No. 14. TEST ON CAST IRON WATER PIPE.

March 25, 1897.

	Thickness.			Inside Diameter.			Length.
	End No. 1.	End No. 2.		End No. 1.	End No. 2.		
A	.87	.90				AA	40″
B	.89	.85	AA′	23.92	23.84	BB	39″
A′	.84	.93				A′A′	39½″
B′	.99	.93	BB′	23.78	23.81	B′B′	39½″

Deflection Measurements.

Loads.	End No. 1.		End No. 2.		Average Difference.	
	AA′.	BB′.	AA′.	BB′.	AA′.	BB′.
0	24.94	24.52	24.87	24.72	.....	....
5,000	24.93	24.54	24.83	24.78	—.025	.040
10,000	24.90	24.57	24.76	24.83	—.050	.040
15,000	24.86	24.62	24.69	24.89	—.055	.055
33,800	Maximum load.	Broke on A′A′; next broke on AA.				
20,000		Broke on BB and B′B′.				

Size of pipe . . . . . 24″
Average inside diameter . . . . . 23.84″
Average length . . . . . 39½″
Average thickness . . . . . .90″

Maximum outside fiber stress calculated from maximum load, assuming each half of pipe as a beam fixed at the ends . . . . . 19,600 lbs.

REMARKS.

Load applied along whole length of specimen.

No. 15. TEST ON CAST IRON WATER PIPE.

March 26, 1897.

	Thickness.			Inside Diameter.			Length.
	End No. 1.	End No. 2.		End No. 1.	End No. 2.		
A	.84	.82				AA	41⅜″
B	.84	.84	AA′	23.84	23.98	BB	41½″
A′	.94	.86				A′A′	41″
B′	.92	.88	BB′	23.95	24.02	B′B′	41½″

Deflection Measurements.

Loads.	End No. 1.		End No. 2.		Average Difference.	
	AA′.	BB′.	AA′.	BB′.	AA′.	BB′.
0	24.74	24.69	24.63	24.58	.....	....
5,000	24.71	24.72	24.56	24.64	—.050	.045
10,000	24.67	24.76	24.50	24.70	—.050	.050
15,000	24.63	24.81	24.43	24.76	—.055	.055
20,000	24.57	24.87	24.35	24.84	—.070	.070
30,700	Maximum load.	Broke at AA, beginning at End No. 1.				
28,400		Broke at A′A′.				
20,800		Broke at BB and B′B′.				

Size of pipe . . . . . 24″
Average inside diameter . . . . . 23.95″
Average length . . . . . 41⅜″
Average thickness . . . . . .87″

Maximum outside fiber stress calculated from maximum load, assuming each half of pipe as a beam fixed at the ends . . . . . 18,200 lbs.

REMARKS.

Load applied along whole length of specimen.

No. 16. TEST ON CAST IRON WATER PIPE.

March 29, 1897.

	Thickness.			Inside Diameter.			Length.
	End No. 1.	End No. 2.		End No. 1.	End No. 2.		
A	.93	.87				AA	40½″
B	.88	.84	AA′	23.83	23.91	BB	40½″
A′	.92	.91				A′A′	40½″
B′	.94	.88	BB′	23.86	23.97	B′B′	40⅜″

Deflection Measurements.

Loads.	End No. 1.		End No. 2.		Average Difference.	
	AA′.	BB′.	AA′.	BB′.	AA′.	BB′.
0	24.46	24.66	24.47	24.66	.....	....
5,000	24.43	24.70	24.41	24.71	—.045	.045
10,000	24.40	24.73	24.37	24.76	—.035	.040
15,000	24.34	24.77	24.29	24.83	—.070	.055
20,000	24.29	24.80	24.25	24.88	—.045	.040
33,600	Maximum load.		Broke on AA, whole length.			
28,600			Broke on A′A′.			
20,700			Broke on B′B′ and BB.			

Size of pipe . . . . . 24″
Average inside diameter . . . . . 23.89″
Average length . . . . . 40½″
Average thickness . . . . . .90″

Maximum outside fiber stress calculated from maximum load, assuming each half of pipe as a beam fixed at the ends . . . . . 19,200 lbs.

REMARKS.

Load applied along whole length of specimen.

No. 17. TEST ON CAST IRON WATER PIPE.

March 30, 1897.

	Thickness.			Inside Diameter.			Length.
	End No. 1.	End No. 2.		End No. 1.	End No. 2.		
A	1.10	1.13				AA	34⅜″
B	1.20	1.16	AA′	30.03	30.02	BB	34⅜″
A′	1.13	1.15				A′A′	34⅜″
B′	1.16	1.17	BB′	29.31	30.00	B′B′	34⅛″

Deflection Measurements.

Loads.	End No. 1.		End No. 2.		Average Difference.	
	AA′.	BB′.	AA′.	BB′.	AA′.	BB′.
0	30.97	30.38	30.45	30 89	.....	....
5,000	30.93	30.41	30.38	30.94	—.055	.040
10,000	30.87	30.47	30 31	30.99	—.065	.055
15,000	30.80	30.52	30.26	31.06	—.060	.060
20,000	30.75	30.58	30.17	31.13	—.070	.065
36,300	Maximum load.		Broke at AA, whole length.			
33,900			Broke at A′A′.			
27,400			Broke at BB.			

Size of pipe . . . . . 30″
Average inside diameter . . . . . 29.84″
Average length . . . . . 34¼″
Average thickness . . . . . 1.15″

Maximum outside fiber stress calculated from maximum load, assuming each half of pipe as a beam fixed at the ends . . . . . 18,700 lbs.

REMARKS.

Load applied along whole length of specimen.

No. 28. TEST ON CAST IRON WATER PIPE.

April 15, 1897.

	Thickness. End No. 1.		Inside Diameter. End No. 1.	Inside Diameter. End No. 2.		Length.
A	1.37				AA	25⅛″
B	1.43	AA′	48.08	48.04	BB	25⅛″
C	1.40				CC	25 ″
D	1.48	BB′	47.86	47.77	DD	25 ″
A′	1.52				A′A″	24⅞″
B′	1.50	CC′	48.02	47.91	B′B″	25 ″
C′	1.52				C′C″	24⅞″
D′	1.45	DD′	47.91	47.97	D′D″	25 ″

Deflection Measurements.

Loads.	End No. 1. AA′.	BB′.	CC′.	DD′.	End No. 2. AA′.	BB′.	CC′.	DD′.	Average Difference. AA′.	BB′.	CC′.	DD′.
0	48.26	48.15	48.26	48.10	48.37	48.07	48.13	48.20	.....	....	....	....
5,000	48.11	48.29	48.27	48.11	48.21	48.20	48.13	48.21	—.160	.135	.005	.010
10,000	47.94	48.47	48.30	48.10	48 03	48.39	48.16	48.21	—.175	.185	.030	—.005
15,000	47.64	48.64	48.33	48.11	47.86	48.55	48.16	48.21	—.235	.165	.015	.005
25,800	Maximum load. Broke at AA, whole length.											
22,800	Broke at A′A″ and B′B″.											

Size of pipe . . . . . 48″
Average inside diameter . . . . . 47.95″
Average length . . . . . 25″
Average thickness . . . . . 1.46″

Maximum outside fiber stress calculated from maximum load, assuming each half of pipe as a beam fixed at the ends . . . . . 17,900 lbs.

Remarks.

Spigot end.
Lip on End No. 2 about ¾″ wide and 1¼″ thick.
Load applied on space of 15″ along center of length of specimen.

No. 29. TEST ON CAST IRON WATER PIPE.

April 17, 1897.

	Thickness.			Inside Diameter.			Length.
	End No. 1.	End No. 2.		End No. 1.	End No. 2.		
A	1.02	1.04	AA′	36.05	36.00	AA	34″
B	1.05	1.12				BB	33¾″
A′	1.09	1.07	BB′	36.08	36.03	A′A′	34″
B′	1.09	1.10				B′B′	34″

Deflection Measurements.

Loads.	End No. 1.		End No. 2.		Average Difference.	
	AA′.	BB′.	AA′.	BB′.	AA′.	BB′.
0	36.31	36.25	36.22	36.25	.....	....
5,000	36.22	36.36	36.13	36.40	—.090	.130
10,000	36.10	36.43	35.97	36.50	—.130	.085
15,000	35.99	36.54	35.85	36.64	—.115	.125
20,000	35.84	36.64	35.72	36.80	—.140	.130
24,200	Maximum load.		Broke on AA, whole length.			
18,600			Broke on A′A′, whole length.			
16,300			Broke on BB, whole length.			
8,300			Broke on B′B′, whole length.			

Size of pipe . . . . . 36″
Average inside diameter . . . . . 36.05″
Average length . . . . . 34″
Average thickness . . . . . 1.07″

Maximum outside fiber stress calculated from maximum load, assuming each half of pipe as a beam fixed at the ends . . . . . 17,300 lbs.

REMARKS.

Load applied along whole length of specimen.

No. 30. TEST ON CAST IRON WATER PIPE.

April 22, 1897.

	Thickness. End No. 1.		Inside Diameter. End No. 1.	Inside Diameter. End No. 2.		Length.
A	1.46				AA	32¼″
B	1.46	AA′	48.14	48.14	BB	32¼″
C	1.47				CC	32 ″
D	1.37	BB′	47.81	48.06	DD	32¼″
A′	1.34				AA′	32¼″
B′	1.45	CC′	48.02	48.14	BB′	32¼″
C′	1.41				CC′	32¼″
D′	1.47	DD′	47.83	48.02	DD′	32¼″

Deflection Measurements.

Loads.	End No. 1. AA′.	BB′.	CC′.	DD′.	End No. 2. AA′.	BB′.	CC′.	DD′.	Average Difference. AA′.	BB′.	CC′.	DD′.
(1) 0	48.44	48.22	.....	.....	48 52	48.02	.....	.....	.....	....	....	....
(2) 0	48.41	48 28	48.38	48 28	48.48	48.07	48.24	48.22	—.035	.055	....	....
5,000	48.31	48.36	48.37	48.28	48.33	48.20	48.25	48 24	—.125	.105	.000	.010
10,000	48.19	48.47	48.38	48.28	48.20	48.31	48.24	48 25	—.125	.110	.000	.005
15,000	48.04	48.57	48.38	48.27	48.06	48.43	48.24	48.24	—.145	.110	.000	—.010
32,300	Maximum load. Broke on AA.											
27,900	Broke on CC and C′C′. (Break at C′C ′about 6″ way from marks, toward AA.)											

Size of pipe	48″	Maximum outside fiber stress calculated	
Average inside diameter	48.02″	from maximum load, assuming each	
Average length	32¼″	half of pipe as a beam fixed at the	
Average thickness	1.43″	ends	18,200 lbs.

REMARKS.

Spigot end.
Lip on End No. 2 about 1″ wide and 1¾″ thick.
Load applied along whole length of specimen.
(1) Pipe resting on B′B′.
(2) Pipe suspended from BB.

No. 31. TEST ON CAST IRON WATER PIPE.

April 27, 1897.

	Thickness. End No. 1.		Inside Diameter. End No. 1.	Inside Diameter. End No. 2.		Length.
A	1.28					
B	1.22	AA′	47.84	47.95	AA	33⅛″
D	1.20				BB	34 ″
A′	1.13	BB′	47.78	48.05	CC	34 ″
B′	1.33				DD	34 ″
D′	1.34	CC′	47.83	47.97	AA′	34 ″
					BB′	33⅜″
		DD′	47.84	47.97	CC′	34⅛″
					DD′	33⅛″

Deflection Measurements.

Loads.	End No. 1. AA′.	BB′.	CC′.	DD′.	End No. 2. AA′.	BB′.	CC′.	DD′.	Average Difference. AA′.	BB′.	CC′.	DD′.
(1) 0	48.19	48.07	48.19	48 09	48 40	48.30	48.33	48.24	.....	....	.....	....
(2) 0	48.16	48.10	48.18	48.08	42.37	48.36	48.34	48.25	—.030	.045	.000	.000
5,000	47.99	48.24	48.18	48.08	48.25	48.50	48.35	48.24	—.145	.140	—.005	.005
10,000	47 82	48.40	48.18	48.08	48.07	48.64	48.36	48.24	—.175	.150	.000	.005
15,000	47.60	48.57	48.18	48.07	48.85	48.81	48.37	48.27	—.220	.170	.000	.005
24,500	Maximum load. Broke on A′A′ through whole length.											
20,300	Broke on AA.											

Size of pipe	48″	Maximum outside fiber stress calculated	
Average inside diameter	47 90″	fro.n maximum load, assuming each	
Average length	34″	half of pipe as a beam fixed at the	
Average thickness	1.25″	ends	17,000 lbs.

REMARKS.

Spigot end.
Lip on End No. 2 about 1″ wide and 1⅛″ thick.
Load applied along whole length of specimen.
(1) Resting on B′B′.
(2) Suspended from BB.

SUMMARY OF TRANSVERSE TESTS ON BARS CUT FROM CAST IRON WATER PIPE.

No. of specimen.	Width.	Depth.	Length of span.	Maximum load.	Deflection at maximum load.	Modulus of rupture.
	Ins.	Ins.	Ins.	Lbs.	Ins.	Lbs. per sq. in.
1	1.99	.50	20	570	.370	34,400
1	2.00	.50	20	635	.443	38,100
2	2.00	.48	20	625	.440	40,700
2	1.99	.50	20	655	.518	39,500
3	2.01	.57	20	720	.345	33,100
3	1.99	.56	20	855	.470	40,500
4	2.02	1.08	24	2,035	.305	31,100
5	2.02	.56	20	700	.520	33,100
5	1.99	.51	20	710	.503	41,200
6	2.01	.73	24	1,170	.594	39,300
7	2.00	.62	20	975	.538	38,100
8	2.00	.70	24	1,315	538	37,900
8	2.00	.79	20	1,665	.420	39,900
9	2.01	.71	24	1,110	.610	39,400
9	2.01	.71	20	1,115	.395	33,000
10	2.01	.74	24	1,350	.680	44,200
10	2.00	.73	20	1,510	.485	42,500
11	2.01	.76	24	1,205	.580	37,400
11	2.00	.73	20	1,250	.360	35,200
12	2.01	.90	24	1,352	.340	29,900
12	2.00	.87	20	1,655	.270	32,800
13	2.02	.71	24	1,455	.515	51,400
13	2.00	.74	20	1,650	.431	45,200
14	2.01	.89	24	1,645	.447	37,200
14	2.00	.86	20	1,830	.296	37,100
15	2.00	.77	24	1,275	.450	38,700
15	2.00	.81	20	1,810	.348	41,400
16	2.02	.91	24	1,644	.442	37,500
16	2.00	.88	20	1,785	.305	34,600
17	2.01	1.11	24	2,272	.395	33,000
17	2.00	1.13	20	2,745	.285	32,200
18	2.01	.56	20	770	.619	36,600
19	2.01	.61	20	930	....	37,300
20	2.00	.50	20	645	.460	38,700
21	2 00	.59	20	880	.540	37,900
22	2.01	.51	20	735	.640	42,200
23	2.01	.71	20	1,240	.560	36,700
24	2.00	.53	20	725	.482	38,700
25	2.01	.64	20	1,020	.549	37,200
26	2.01	.50	20	595	.670	35,500
26	2 00	.46	20	560	.783	39,700
27	2.02	.56	20	600	.360	28,400
27	2.02	.55	20	660	.410	32,400
28	2.00	1.41	24	3,685	.342	33,400
29	2.01	1.02	24	1,820	.395	31,300
29	2.00	.96	20	2,235	.266	36,400
30	2.03	1.37	24	3,445	.308	32,600
31	2.00	1.24	24	2,492	.244	29,200
31	2.00	1.22	20	3,215	.205	32,400

NOTE. — These bars were cut from the broken specimens of the water pipe, the numbers indicating the pipes from which the samples were cut.

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[1] Published in Technology Quarterly, Vols. VII to IX (1894 to 1896). The Roman numerals in the index refer to the volume of the Quarterly. The numerals in parentheses indicate the part of the *Tests*.

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